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The impact of verbal instruction type on movement learning and performance: A
multidisciplinary investigation of analogy and explicit instruction

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PhD

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2016

Author Declaration

I hereby declare that:

- a) I have composed this thesis,
- b) This thesis is my own work,
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Ray Bobrownicki

26 April 2016

Abstract

The aim of this thesis was to investigate and appraise the utility of analogy and explicit instruction for applied sport and physical education settings. The objective for the first study was to explore the acute, short-term impact of analogical and explicit instruction in a dart-throwing task. While previous studies have devoted considerable resources to investigating the effects of verbal instruction on motor *learning*, this within-subjects study explored the impact of analogical and explicit instruction on motor *control*. Interestingly, results indicated that analogy and explicit instruction similarly impaired throwing accuracy—in both kinematic and outcome measures—compared to baseline conditions, conflicting with trends observed in the motor learning literature. In the second study, the differential effects of analogy and explicit instructions on early stage motor learning were examined by introducing an explicit light condition—in addition to a traditional explicit condition—that matched the analogy instructions in informational volume. Although analogy learners demonstrated slightly more efficient technique and reported fewer technical rules on average, the differences between groups were not statistically significant. Kinematic analysis, however, did reveal significant differences between conditions in joint variability, which decreased with learning for all groups, but was lowest overall for the analogy learners. For the final study, the thesis investigated the impact of analogy and explicit instruction on adolescent performance (mean age = 12.7 years, $SD = 0.4$) in a modified high jump task. To date, research in analogy instruction has only included adult participants whose movement tendencies have likely already been shaped by personal or vicarious experiences. Analyses indicated that there were no significant differences between the analogy and explicit participants in technical efficiency or joint variability. The key outcome from this thesis is that there is limited evidence to support the use of analogy instruction over explicit instructional methods in motor learning and motor control situations.

Lay Summary

The aim of this thesis was to examine and compare the effects of two different types of verbal information—analogy and step-by-step, explicit instruction—on movement and performance for use in sport and physical education settings. As numerous studies have demonstrated an association between choking under pressure and explicit knowledge, researchers have increasingly advocated the use of analogies, over explicit instruction, in order to prevent possible skill failure later on. Limitations in previous research, however, have made it uncertain whether analogies truly offer any inherent benefit over traditional, explicit teaching methods. To gain greater insight in this regard, this thesis addressed those limitations by building upon the methods of previous research to appraise these two instructional types in three studies. In two of these studies, results revealed no significant differences between analogy and explicit instructions in skills practised over several days, provided the instructions sets were comparable in length. In short-term scenarios, participants again performed similarly in both the analogy and explicit conditions, although performance was best in the control conditions in which no instruction was provided. The collective findings of this thesis offer limited evidence to support the use of analogies over traditional instructional methods—provided the instructions are of corresponding length—and that coaches and sport psychologists may want to consider exploring new options for teaching sports and movement skills.

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I would also like to thank my parents for their support over the years. Although I am sure they wished I lived closer to home, they have always stood behind me in my personal, sporting, and academic endeavours and permitted me the freedom to explore my own interests. For this, I am immensely grateful.

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List of Publications and Presentations

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¹ Based on the study reported in chapter 4 of this thesis

² Relates to the information presented in chapters 4 and 5

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Chapter 1. Introduction

Chapter Aims

The aim of this chapter is to establish the topic, structure, and purpose of this thesis and the research herein. At the start, a short introduction to analogy and explicit instructional methods is provided that briefly discusses the rationale and background for research in this area. From here, delimitations of the thesis are established, theoretical and methodological challenges discussed, and the aims of the research identified. Upon identification of the aims of the thesis, the chapter concludes with an overview of the thesis structure by outlining the content and objectives on a chapter-by-chapter basis.

1.1. Introduction

In applied settings, sport psychologists must often develop interventions that require athletes to modify ineffectual or problematic thoughts or behaviours. Although the provision of support might not always directly relate to sporting performance, the expectation is that these strategies—such as goal setting or self-talk—will ultimately improve performance outcomes. There is less consideration, however, for the implications of cognitive-behavioural interventions on the *movement* that underpins those performance outcomes, even for approaches that explicitly involve motor learning. For instance, analogy learning—a verbal teaching method first proposed by Masters (2000)—has received considerable interest from researchers as a means of preventing skill breakdown under pressure (i.e., choking), yet only one empirical study, to date, has explored its impact on movement mechanics compared to traditional explicit instructional methods (see Lam, Maxwell,

& Masters, 2009b). This is particularly regrettable in the case of analogy instruction as the aesthetics, efficiency, and consistency of movement constitute fundamental factors in realising peak states and can often represent primary measures of sporting performance (e.g., diving, figure skating, and gymnastics).

The larger, underlying issue, however, is that sport science research such as this often has limited application to authentic sports settings (Ericsson & Williams, 2007). In the case of analogy and explicit instructions, research designs have concentrated on examining their impact within a narrow set of parameters that do not necessarily reflect the breadth and authenticity of real-world sporting environments. Although this has not stopped researchers from advocating its application across a variety of domains, ranging from professional sport (e.g., Gabbett & Masters, 2011) to surgical training environments (e.g., Masters, Poolton, Abernethy, & Patil, 2008), the implications of its use in contexts such as these are unclear, because of methodological limitations and unaddressed gaps in knowledge in the existing analogy and explicit instruction literature. To offer better guidance to sport psychologists and the coaches and athletes with whom they work, research in analogy and explicit instruction must incorporate more task-relevant methods and move beyond simple examination of performance outcomes. This thesis seeks to build upon the existing literature to investigate the differential impact of analogy and explicit instruction on movement and performance.

1.2. Establishing boundaries

As analogy learning was designed as an instructional tool for administration during the skill acquisition stage (Masters, 2000), the research studies of this thesis

concentrate on its impact on novices. Matching precedent from the literature (e.g., Poolton, Masters, & Maxwell, 2006, 2007b), participants were considered beginners if they had not received any formal coaching instruction in the task prior to their involvement in the research. Because the original aim of implicit teaching methods, however, was to forestall skill breakdown at more advanced stages of performance (Masters, 1992), the implications of the research findings on experienced athletes are considered, although they were not actively investigated.

This thesis also concentrates on the differential effects of analogy and explicit instruction on *self-paced gross motor skills*. While team performance represents an important consideration for coaches, physical educators, and sport psychologists, the complexity involved in examining movement mechanics from a group perspective makes such investigations impractical, especially as even individual motor performances comprise a nearly infinite number of possible joint configurations (Bernstein, 1967). A focus on individual, self-paced motor skills also facilitates comparison to existing research in this area.

1.3. Theoretical and methodological challenges

As it is impractical, if not invasive, to investigate the neurological effects of verbal instruction in real-time gross and fine motor performances, sport psychology research must often incorporate indirect measures to investigate important concepts and phenomena. While a number of methods in psychology-related research are commonplace and straightforward, such as surveys or questionnaires, understanding how different types of verbal instruction affect learning and impact upon movement requires a multidisciplinary approach. For this reason, biomechanics constituted a

critical component of the research in this thesis. It should be stressed, however, that this is not a doctoral thesis in biomechanics, but a sport psychology thesis that incorporated biomechanical measures to understand how analogy and explicit instructions influence movement mechanics and, by extension, to better inform applied practitioners regarding their use.

Although the inclusion of biomechanical measures in this research offered the potential for additional insights regarding the differential effects of analogy and explicit instruction for both theoretical and applied perspectives, it also imposed significant constraints on participant recruitment. In this regard, there are limited body segment parameter data available for conducting kinematic analyses involving groups other than adult males, as the relevant data are derived from male cadavers (e.g., Dempster, 1955). Consequently, females, regardless of age, could not be recruited for the studies reported in chapters 4 and 5, which required these body segment parameter data. In the case of chapter 5, age-based regression equations (Jensen, 1986) were utilised to estimate paediatric body segment parameters in order to facilitate the recruitment and inclusion of adolescent males in the research.

1.4. Intended audience and clarification of terminology

Although the impetus of research in implicit and analogy learning ultimately derives from sport psychology-related principles pertaining to choking and elite sport, investigations in analogy and explicit instruction concern the differential effects of these instructional types on *novice* skill learning. Consequently, the experiments from this thesis, the results, and their implications will have relevance not simply to sport psychologists and elite performers, but also across a range of

disciplines, including youth sport, physical education, and sport pedagogy. As such, the research herein will have significance to those practising or instructing; such as physical educators, coaches, sport psychologists, and movement practitioners; those learning or performing, such as physical education students, athletes; and also those conducting research relating to these aforementioned groups. Further enhancing the multidisciplinary relevance of this thesis is the incorporation of biomechanical and physiological measures, which ought to provide more comprehensive insight and understanding than earlier studies, which have focused on evaluating these methods using outcome-based methods.

While a strength of this thesis, its multidisciplinary nature—combined with the limitations of the English language—can make it difficult at times to adequately convey the concepts, findings, and implications of this thesis with regard to all of the disciplines involved. For instance, discussing the implications of a specific finding for *athletes* without explicitly mentioning physical education *students* could implicitly suggest that the findings may not apply to students. Rather than always refer to students and athletes in every instance, the terms *learner* and *performer* are used in this thesis in their purest sense (i.e., one who is learning and one who is performing a task, respectively) and intended as general terms that apply to both physical education and sport. Adjectives such *elite* or *skilled* will be used to describe and distinguish expert performers and expert performances from the performances of novice athletes and physical education students where necessary.

1.5. Aims and objectives of the thesis

The primary aim of this thesis was to investigate and appraise the differential effects of analogy and explicit instruction on movement and performance. To accomplish this, the first step was to explore and evaluate recent research in the area. During this process, the prevailing perspectives on the effects of analogy and explicit instruction were established, the methodology of the earlier studies examined, and the limitations of these studies discussed. Of particular importance at this stage was to identify the methods and measures that would maximise the application of research in this area to authentic sport and physical education settings, either by modifying existing practices or by incorporating novel approaches.

These recommendations from this critical evaluation of the literature subsequently guided the development and progress of the second stage of the thesis, the empirical research, which had several main objectives. First, the impact of analogy and explicit instruction on motor control was investigated to determine the acute, short-term effects of these verbal instructional types. The second of these was to examine the role of instructional volume as a moderator of the effects of analogy and explicit instruction. Third, the effect of analogy and explicit instruction on adolescents was investigated for the first time to see if age or task novelty influenced the nature of learning with respect to instructional type. Finally, the last objective, which permeated all of the research, was to determine how analogy and explicit instruction influence movement mechanics. The impact of these instructional types on joint variability represented a particularly important consideration both within and across all of the studies. While the associated research was primarily laboratory based, the designs of these empirical studies were intended to represent the

conditions experienced by learners and performers in order to enhance the utility of the research to interested parties. The following section details how these objectives were approached.

1.6. Thesis overview

Upon establishing the purpose, structure, and aims of the thesis in this initial chapter, chapter 2 explores the background, development, and significance of analogy and explicit instructional methods from a sport psychology perspective, while critically examining the extant literature related to these concepts. In doing so, this chapter provides the rationale and context for the studies that constitute the research programme of this thesis.

The first of these studies, reported in Chapter 3, investigates and compares the short-term impact of analogy and explicit instruction on motor control in a dart-throwing task. To date, research involving analogy and explicit instructions has concentrated on their effects on motor learning with little consideration for their impact on motor control. Using a within-subjects design, this study examines throwing accuracy, kinematics, and elbow joint variability to assess the acute effects of the verbal instruction types.

In chapter 4, concerns regarding informational imbalance in previous studies are addressed by introducing an explicit condition with reduced instructional volume—compared to traditional explicit conditions—in a modified high jump task. Over the course of several days, participants learned and performed a high jump technique using one of three types of instruction: analogy, explicit light (reduced informational load), and traditional explicit (normal informational load). Bar height

was employed as a task-relevant pressure to better match the pressure and sporting conditions of the study with those experienced in authentic performance settings. The effects of the instructional types are evaluated by examining the efficiency of the technique and the variability around the mean for the knee and hip joints.

In the third study of the thesis, detailed in chapter 5, the design builds upon the foundation and findings of the previous chapter by employing similar methods to investigate the impact of analogy and explicit instruction on novice adolescents. By recruiting younger participants, a potential issue pertaining to task novelty identified in chapter 4 was also addressed. Once again, movement mechanics and performance with respect to instructional type are assessed by analysing the efficiency of the technique and joint variability.

The general discussion, contained in chapter 6, summarises the results of the three research studies, contextualises those findings—and their implications—from both research and applied perspectives, and discusses the limitations of the research in this thesis. Taken together, the chapter concludes by exploring possible avenues for future investigation.

Chapter 2. Literature Review

Chapter Aims

This chapter explores and appraises recent research relating to analogy and explicit instruction, while establishing the background, development, and significance of these instructional methods. As part of this process, the theoretical and methodological limitations of the preceding research output are identified and, where appropriate, recommendations for addressing these limitations are discussed. This discussion of the literature and key concepts relating to analogy and explicit instruction provide an empirical basis for the hypotheses of this thesis, which are stated at the end of the chapter.

2.1. Performance failure and the role of explicit information

In elite sport, athletes invest considerable time and effort so that they can perform at their peak on the biggest stages. Despite the dedicated training, however, these important moments do not always unfold as planned, as performance pressure can often disrupt the execution of ordinarily autonomous skills (Lam, Maxwell, & Masters, 2009a), resulting in performance far below expectations. This phenomenon of unexpected, acute performance impairment—popularly known as ‘choking under pressure’—has received considerable attention in the literature over the past few decades, as the ability to perform under pressure represents a key aspect of elite sport (Mesagno & Mullane-Grant, 2010). To explain its effects, two categories of theories have emerged: arousal theories and attentional theories (Hill, Hanton, Matthews, & Fleming, 2010). According to the arousal-related theories, inappropriate levels of activation, influenced by a desire to perform well, negatively impact performance

(Spence & Spence, 1966). According to Hill et al. (2010), however, two attention-based theories have emerged in this time as the most likely explanations of the phenomenon. In the first of these, known as the distraction theories, pressure-induced anxiety consumes working memory resources that ordinarily manage movement-related information (Sarason, 1988). The task-irrelevant information subsequently compromises processing efficiency, leading to performance deterioration (J. Hardy, Mullen, & Martin, 2001; Mullen, Hardy, & Tattersall, 2005). According to the most prominent of the distraction theories, processing efficiency theory (PET; Eysenck & Calvo, 1992), this skill breakdown—due to insufficient capacity—can be moderated by effort, which mobilises auxiliary attentional resources to the task.

According to the self-focus theories, which constitute the second of the attentional theories, performance anxiety promotes the active monitoring or manipulation of typically automatised processes in working memory, thereby disrupting execution (Gucciardi & Dimmock, 2008; L. Hardy, Mullen, & Jones, 1996; Masters, 1992). In essence, the inward focus of attention engendered by anxiety disrupts performance because athletes attend to or assume control of processes they would otherwise never control. These self-focus theories are tightly intertwined with the traditional cognitive framework of motor skill acquisition (Anderson, 1982; Fitts & Posner, 1967) which posits that the attentional demands and knowledge that underlie motor performance differ with respect to expertise. Although more advanced performance relies on automatised procedural systems that require little conscious attention, the early stages of skill learning involve the effortful serial processing of explicit, rule-based knowledge in working memory systems in order to approximate the successive steps of motor execution. These

differences in the attentional demands and underpinning knowledge represent the basis for the development of the most prominent self-focus theories: the explicit monitoring hypothesis (EMH; Beilock & Carr, 2001) and the conscious processing hypothesis (CPH; Masters, 1992). In the EMH, disruption occurs when performers actively *monitor* their movement, whereas performance breaks down in the CPH only when movement is consciously *controlled*. According to Masters (1992), in the CPH, performance pressure causes skilled performers to ‘reinvest’ any residual explicit, conscious knowledge regarding the task back into the movement, effectively regressing them to earlier stages of learning. In other words, experts abandon their ordinarily automatised processes underpinned by procedural knowledge and revert to the skill-focused, step-by-step processing of rule-based, explicit knowledge that characterises novice performance. This reinvestment of explicit information outstrips working memory resources, impairs the processing of task-relevant information, and, therefore, increases the likelihood of performance errors (Masters & Maxwell, 2008).

2.2. An intervention to prevent choking: Implicit learning

While the majority of interventions designed to prevent choking have predominantly focused on the reduction of anxiety or the amelioration of the effects associated with that anxiety during performance (Lam et al., 2009a), Masters (1992) argued that an intervention during the skill acquisition stage might prove more effective. As explicit knowledge is thought to engender the skill-focused attention associated with choking, Masters (1992) proposed that restricting the accumulation of verbal, rule-based information during learning might forestall skill failure at later stages of performance, as elite performers would have limited explicit knowledge to

reinvest into their ordinarily autonomous skills. In other words, performers would acquire their skills implicitly outside conscious awareness, preventing them from engaging in the deleterious behaviours associated with the CPH. Because many coaches consider such prescriptive, rule-based instructions necessary for skill learning (Hodges & Lee, 1999), as they specify the ideal movement model to the learner (Davids, Button, & Bennett, 2008), Masters' proposal presented curious possibilities with potentially far reaching implications. Across many sports, this common, authoritarian approach to skill instruction is typified by the coach imparting his knowledge to the learner through detailed verbal instruction (Williams & Hodges, 2005).

The inspiration and basis for such implicit instructional methods first emerged from psychological research involving complex cognitive tasks, which demonstrated that individuals can learn to perform complex tasks without any conscious awareness or accumulation of verbal knowledge regarding that task (e.g., Allen & Reber, 1980; Berry & Broadbent, 1984, 1988; Broadbent, Fitzgerald, & Broadbent, 1986). In the first of these studies, Reber (1967) found that untaught participants, after simply memorising strings of letters with artificial grammatical rules, could better identify incorrect examples of that grammar than participants that had been taught the rules of the synthetic language beforehand, although those uninstructed participants had no knowledge or understanding of how they had even done so. By learning passively, implicit learners in these studies were demonstrating characteristics that were more typically associated with experts, rather than the rule-based, declarative learning associated with novices, which suggested intriguing possibilities for the acquisition of motor skills.

To apply such methods to the learning of movement skills, Masters (1992) hypothesised that implicit techniques should aim to occupy working memory, as it is implicated in the maintenance and manipulation of rule-based, movement knowledge (Lam et al., 2009a). According to Masters, even in the absence of explicit instructions, learners could still accumulate rule-based knowledge through hypothesis testing, whereby external feedback and knowledge of results facilitate the development and appraisal of conscious movement strategies. By engaging working memory systems with unrelated tasks, the learners would be unable to generate any explicit information or strategies regarding the movement, while still passively acquiring the task knowledge necessary to perform it. Masters' (1992) research supported this hypothesis, as golf-putting skills acquired implicitly—without reliance on rule-based instruction or working memory systems—were more resilient to induced stressful conditions than those same skills gained through traditional explicit means. Later research using similar methodological designs replicated these findings, demonstrating that passively acquired motor skills were more robust to performance pressure and concurrent cognitive demands than skills underpinned by explicit, declarative knowledge (e.g., J. Hardy et al., 2001; L. Hardy et al., 1996).

2.3. Benefits of implicit learning

To date, studies have extended the benefits of implicit learning over traditional explicit methods to a diverse range of motor skills including table tennis forehands (Liao & Masters, 2001), balancing tasks (Orrell, Eves, & Masters, 2006), rugby passing (Poolton, Masters, & Maxwell, 2007a), and golf putting (L. Hardy et al., 1996; Masters, 1992; Maxwell, Masters, & Eves, 2000; Mullen & Hardy, 2000).

Across these various domains, several advantages associated with implicitly acquired skills have emerged. These benefits are detailed below.

2.3.1. Reduced explicit knowledge

As part of the inspiration for the development of implicit learning methods was to restrict the accumulation of rule-based, verbal knowledge, Masters (1992) developed the verbal protocol questionnaire to measure the accumulation of explicit rules regarding task performance. In these written protocols, which have been used in many of the studies involving implicit and explicit instructional methods to date, participants are asked to describe in detail any technical or mechanical aspects they can remember regarding task performance. Throughout the implicit learning literature, implicit learners have reported significantly fewer verbal rules on average than their explicit learning counterparts (e.g., Liao & Masters, 2001; Masters, 1992; Maxwell et al., 2000), which has positive benefits for performance, according to the CPH.

2.3.2. More robust performance under pressure

By restricting the accumulation of verbal knowledge, Masters' (1992) ultimate aim was to design an intervention to prevent choking under pressure. With less declarative information available to conscious processes regarding task performance, learners would have limited knowledge to reinvest into the skill, thereby pre-empting movement disruption, according to the CPH. Using several different methods to evoke anxiety, such as evaluation (e.g., L. Hardy et al., 1996; Masters, 1992; Mullen & Hardy, 2000), prize money (e.g., L. Hardy et al., 1996; Masters, 1992; Mullen &

Hardy, 2000), and tone counting (e.g., Maxwell et al., 2000), research indicates that performances underpinned by implicitly learned skills are less susceptible to skill disruption under stressful conditions than those acquired explicitly. It should be noted, however, that implicit learning, while more robust under pressure, did result in slower rates of learning under normal conditions compared to explicit methods in many of these studies (e.g., L. Hardy et al., 1996; Masters, 1992; Maxwell et al., 2000).

2.3.3. More robust performance under physiological fatigue

From a biological and evolutionary perspective, Reber (1992) argued that implicit systems are likely more robust and durable than explicit processes, as any non-verbal skills would have emerged much earlier in the course of human development. To investigate this conceptual framework in motor skill learning, Poolton et al. (2007a) examined the effects of physiological fatigue on rugby passing in novices. After learning the technique over 100 trials in the learning phase, participants then had to perform the same passing accuracy test under dual-task conditions (random letter generation; Baddeley, 1966) and then under fatigued conditions in the test phase. Upon completing two Wingate anaerobic tests (Inbar, Bar-Or, & Skinner, 1996), participants in the implicit condition demonstrated less disruption under physically demanding conditions than participants from the explicit learning condition. Interestingly, however, a retention test one year following the initial research indicated that the passing skills of both explicit and implicit learners were resilient to fatigue. According to Poolton et al., the resilient performance of the explicit condition in the retention test suggests a ‘decay’ of declarative knowledge.

After examining robustness under anaerobic conditions, Masters, Poolton, and Maxwell (2008) extended this line of research to aerobic fatigue, which they surmised would also have a strong evolutionary basis. Using a similar design, implicit and explicit learners again learned a rugby-passing task and then performed both a dual-task transfer test (random letter generation) and then a fatigued performance transfer test (performed following an exhausting VO₂ max. running test). Although the explicit learners demonstrated more accurate passing under normal conditions, the performances of the implicit learners were less susceptible to skill disruption under both dual-task and aerobically fatigued conditions.

2.3.4. Increased attentional capacity for other tasks

As working memory is occupied, the findings from these implicit learning studies suggest that passive learning requires less conscious attention than explicit methods. Consequently, learners should have spare attentional capacity for handling, processing, or reacting to additional environmental information or demands (Masters, 1992; Maxwell, Masters, & Eves, 2003), a capability that is typically associated with expert performance. As automatised control requiring little conscious attention was customarily thought to emerge as a function of learning, according to the traditional cognitive framework for skill acquisition, the possibility that implicit learners could demonstrate these characteristics early in learning represented a compelling development.

2.4. Implicit learning methods

To facilitate implicit motor learning, researchers have aimed to restrict the accumulation of explicit knowledge regarding task performance by limiting verbal

instructions and disengaging working memory systems from active involvement in movement mechanics. Over the past 25 years, researchers have devised a range of strategies to occupy working memory to facilitate the passive acquisition of motor skills without any reliance on explicit information. These strategies are discussed below.

2.4.1. Dual-task learning

In the seminal implicit motor learning study, Masters (1992) promoted passive learning by asking implicit participants to perform a random letter generation task adapted from Baddeley (1966). In Masters' study, participants were required to call out a random letter after each click of an electronic metronome, which sounded every 1.5 s initially, but was reduced to 1 s for the final two learning sessions. The frequent clicks were intended to prevent implicit learners from diverting conscious attention away from the letter task and toward the golf-putting task. Since this first implicit learning study, similar random letter generation tasks have subsequently been employed across the implicit learning literature (e.g., L. Hardy et al., 1996; Mullen & Hardy, 2000). Other researchers, such as Maxwell et al. (2000), have employed comparable tasks such as tone counting to similarly engage working memory and facilitate implicit learning.

2.4.2. Errorless and reduced-feedback learning

Another implicit learning strategy used in the implicit learning literature is errorless or reduced-feedback learning (e.g., Masters, MacMahon, & Pall, 2004; Masters, Maxwell, & Eves, 2009; Maxwell et al., 2003; Maxwell, Masters, Kerr, &

Weedon, 2001). Rather than prevent hypothesis testing by occupying working memory, researchers instead aimed to reduce the information available for hypothesis testing by either minimising participant mistakes or by restricting access to knowledge regarding performance results. Without any knowledge or awareness of performance errors, learners would be less likely to generate explicit rules to eliminate those errors. To implement an errorless learning strategy, researchers, for example, have asked participants to start practising passing accuracy tasks in rugby (e.g., Masters, Poolton, & Maxwell, 2008; Poolton et al., 2007a) closer to their targets than their explicit counterparts, so that they would be exposed to fewer errors early in learning, before incrementally moving them back in distance. Research (Poolton, Masters, & Maxwell, 2005) suggests that even brief exposure to errorless learning conditions early in learning reduces the likelihood for hypothesis testing, even if explicit rules are eventually introduced.

2.4.3. Subliminal learning

Borrowing elements of reduced-feedback learning, Masters et al. (2009) concealed the target of a golf-putting task using a curtain, but intermittently presented learners with feedback of their performance at three thresholds of awareness: at the supraliminal threshold (available to conscious awareness), at the subjective threshold (available at the subliminal level), and the objective threshold (unavailable to perception). During the learning phase, participants in the supraliminal and subjective threshold conditions demonstrated improvements in putting accuracy, while the objective threshold participants did not. In the transfer test, however, during which the putting target was now visible, performance

increased for only those participants in the subjective and objective conditions for which feedback was always below conscious awareness. The researchers concluded that the restricted visual feedback successfully facilitated implicit learning processes by limiting the hypothesis-testing practices associated with choking under pressure.

2.5. Issues with implicit learning methods

By employing these passive learning strategies, implicit learners performed better under stressful and fatigued conditions than their explicitly taught counterparts, ostensibly because they had less rule-based knowledge to reinvest into their movements. Despite such promising findings in the laboratory, however, these implicit instructional methods have seen limited application in the field. Much of the difficulty in this regard stems from the cumbersome and logistically demanding implementation of these methods. As Poolton, Masters, and Maxwell (2006) explained, ‘implicit motor learning paradigms are ecologically challenged, generally difficult to apply in the field, and result in slower learning than normal’ (p. 678). While researchers may be able to administer implicit techniques, such as dual-task, errorless, and subliminal learning, in well-controlled laboratory settings in which participants attend individually, it is unrealistic for many coaches and physical educators to apply these strategies as readily to athletes or students—especially larger groups—in real-world settings. The reduced rates of learning observed in many of these studies may also serve to discourage practitioners from employing implicit methods, despite the purported benefits of these passive instructional methods under pressure.

2.6. The advent of analogy

Recognising the need for more practical implicit instructional methods, Masters (2000) proposed the concept of ‘coaching by analogy’ in which a series of complex movements or behaviours is conveyed through a single analogical cue. The premise is that such ‘all encompassing biomechanical metaphors’ can concisely convey movement information and effectively ‘camouflage’ explicit rules. The primary advantage of analogies—over earlier implicit instructional methods—is that they can be readily incorporated into existing coaching and instructional paradigms, as they do not require unusual modifications to the learning environment, as in errorless or subliminal learning, but simply an adjustment in the type of information (i.e., analogies versus explicit rules).

In the first study to investigate analogy instruction empirically, Liao and Masters (2001) randomly assigned table tennis novices to one of three topspin forehand instructional conditions: analogy, explicit, and implicit. For the analogy condition, participants were instructed to ‘pretend to draw a right-angled triangle with the bat’ and to ‘strike the ball while bringing the bat up the hypotenuse of that triangle’ in order to apply the spin. In the case of the explicit learners, however, participants received a detailed list of 12 separate steps for the topspin forehand technique. Unlike the other two conditions, technical instruction was never provided to those in the implicit condition; instead, these participants were asked to perform a concurrent secondary task—random letter generation—during the skill acquisition phase of the study. Using the instructions for their respective conditions, the participants learned the technique over the course of six blocks of 50 trials (300 total trials) in the skill acquisition phase. The test phase comprised a transfer test—during

which all participants also performed the pressure-inducing secondary task (backwards counting)—and a retention test. The aim for each participant was to hit the table tennis ball into a target area using the forehand technique. Points were awarded based on where the balls landed within the target area, which was divided into four, clearly marked scoring zones. Results showed that participants in the explicit condition experienced significantly greater performance impairment during the transfer test and accumulated significantly more explicit rules—according to a verbal protocol questionnaire—than their counterparts in the analogy and implicit conditions.

Building upon the methodology of this study, Law, Masters, Bray, Eves, and Bardswell (2003) also explored the impact of analogy and explicit instruction on table tennis technique, but instead evaluated performance in the presence of three types of audiences: observational, supportive, and adversarial. As the researchers expected, the analogy learners demonstrated consistent performance across the three audience types, while the explicit learners exhibited impaired performance in front of the supportive crowd. Unexpectedly, the explicit learners were unaffected by the adversarial audience, suggesting that supportive audiences may engender greater self-awareness regarding movement. It should also be noted that the analogy learners—while unperturbed by the audience manipulation—did not perform as well during the acquisition phase as their explicit counterparts, corresponding with the slower learning exhibited in earlier implicit learning studies.

In 2006, Poolton et al. examined the role of verbal instructional type in the interaction between movement control and decision-making. Participants once again learned the topspin forehand technique using either a simple analogy or a set of

explicit instructions. Learning and performance were then evaluated by asking participants to hit the table tennis ball to a specific direction depending on the colour of the ball in low complexity (white and yellow balls to the left and right targets, respectively) and high complexity conditions (the colour–target relationship switched after every two trials). Results revealed that performance was unaffected by the low-complexity decisions, but that explicit learners exhibited relative performance impairment during the complex decision-making task. Once more, however, the analogy learners demonstrated generally slower learning than their explicit counterparts, despite their robust and consistent performance in both decision-making manipulations.

2.7. Moving beyond table tennis

Recognising that studies comparing analogy and explicit instruction had focused predominantly on table tennis, Lam et al. (2009b) extended the investigation to a new task: seated basketball shooting. This was also the first study to examine the differential impact of analogy and explicit instructions on movement mechanics, employing biomechanical measures to investigate the kinematics of shooting performance. Over the course of three days, participants learned the shooting task in one of three conditions: analogy (single analogical cue), explicit (list of eight step-by-step rules), or control (no instruction). On the fourth day, the test phase, participants performed a retention test, a secondary task transfer test (backward counting task), and another retention test. Although the analogy group exhibited the best shooting performance on average across the test phase and did not experience any deterioration during the transfer test, unlike the other two conditions, the results

did not reach statistical significance. For the learning phase, it was the explicit learners that demonstrated the best shooting performance on average, but these results were again non-significant. In contrast to the preceding table tennis studies, which used an objective measure of performance (i.e., target accuracy), performance in this instance was assessed using a subjective 6-point scale from Hardy and Parfitt (1991), which could have lessened measureable differences between groups. With regard to movement mechanics, analyses did not reveal group differences for kinematic variables, despite analogy learners reporting significantly fewer technical rules. Given the non-significant findings for shooting performance, the results for basketball shooting were not as favourable toward analogies as the table tennis investigations, although the findings on average still corresponded with the trends of those earlier studies. The incorporation of biomechanical measures and the change in task, however, represented much needed progress in research design.

This was not to be the only study to use seated basketball shooting, however, as Lam et al. (2009a) employed a similar task and methodology. In this instance, however the researchers investigated probe reaction times—rather than kinematics—with respect to instructional type. Using either a single analogical cue or eight explicit rules, participants learned and performed a seated basketball-shooting task over a two-day learning phase and a single day of testing. For this study, the one-day test phase comprised three distinct parts: a retention test, a transfer test under expert evaluation, and a second retention test. Throughout both of these phases, participants were asked to verbally respond to any auditory tones, which were presented both during and between shots, as quickly as possible to assess probe reaction times. Although there were no significant between-group differences during the learning

and testing phases with regard to shooting performance, which was subjectively assessed, there was a significant interaction between condition and block during the testing phase. This interaction indicated that the performance of the explicit group deteriorated significantly relative to their performance levels in the retention tests, while analogy learners demonstrated the opposite trend. For probe reaction time, which was introduced to examine attentional capacity, analyses revealed no significant differences between analogy and explicit learners, suggesting that attentional processing was equally efficient in both groups. It is interesting to note that probe reaction times increased for both groups during the transfer test, indicating that both analogy and explicit learners committed more attentional resources to the shooting task, but performance only decreased for the explicit instruction condition. According to the researchers, this suggests that the performance impairment under pressure may not result due to inefficiency in working memory or attentional processes (cf. Gucciardi & Dimmock, 2008), but due to the amount of verbal knowledge acquired, as learners in the explicit condition reported significantly more explicit rules regarding the task than participants in the analogy condition. This interpretation corresponds with the findings of Koedijker, Oudejans, and Beek (2007) who found that performance disruption in a table tennis task was associated with the accumulation of verbal knowledge, but not the attentional focus of the instruction (i.e., internally or externally focused).

2.8. The effect of time constraints and attention

In a more recent study, Koedijker et al. (2011) returned to the sport of table tennis once again to investigate the impact of attention and time constraints with

respect to instructional type on motor learning and performance. In their study, modelled after the work of Beilock and colleagues (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Carr, MacMahon, & Starkes, 2002), participants used either one simple analogy or five explicit rules regarding table tennis technique to hit table tennis balls to a target in five different conditions: single task (baseline), skill-focused (reported moment paddle contacted ball), dual-task (listening to and repeating target phrases), slowed (ball frequency slowed to 20/min from 30/min), and speeded (ball frequency increased to 40/min). Compared to the single task conditions, the explicit learners demonstrated less accurate performance in both the skill-focused and dual-task conditions, while analogy learners were only adversely affected by the skill-focused condition. Interestingly, the pattern of the results for the explicit and analogy learners in the single, skill-focused, and dual-task conditions corresponds with the findings for beginners and experts, respectively, in a golf putting study by Beilock, Carr et al. (2002). Because analogy learners also reported fewer technical rules in their verbal protocol questionnaires than their explicit counterparts, the researchers argued that the participants in the analogy condition might have completely bypassed the early, declarative stage of learning according to the cognitive framework for skill acquisition. The analogy and explicit learners, however, were similarly affected by the changes in ball frequency, as both maintained performance during the slowed condition, but lost accuracy when delivery rates of the ball were increased. While this does not necessarily reflect the typical novice-expert pattern, as in the other conditions, the analogy learners did perform slightly better on average in the speeded task, suggesting that the

deterioration in accuracy could have been dexterity-related and not necessarily due to deficits in attention.

2.9. A closer look at the analogy and explicit instruction literature

Throughout the analogy and explicit instruction literature explored to this point, research has shown that participants learning tasks through analogical instruction report fewer task-relevant rules (Koedijker et al., 2011; Lam et al., 2009a, 2009b; Law et al., 2003; Liao & Masters, 2001; Poolton et al., 2006, 2007b), exhibit no deficits in kinematic variables (Lam et al., 2009b), and perform without disruption under evaluative (Lam et al., 2009a; Law et al., 2003) or dual-task conditions (Koedijker et al., 2011; Lam et al., 2009b; Liao & Masters, 2001; Poolton et al., 2007b). The research of Koedijker et al. (2011) even showed the performances and attentional tendencies of analogy learners to correspond with those of expert performers in the motor learning literature. For an applied sport psychologist, on the surface, this represents mounting evidence to favour the use of analogies over explicit methods for instructing novices. Unfortunately, however, upon critical examination, there are limitations in the previous research methodology that cast doubt upon the benefits of analogy learning compared to traditional explicit instructions. The following section explores and identifies issues in the existing literature that represent important considerations for both researchers investigating analogy and explicit instruction and practitioners applying these instructional methods in the field.

2.9.1. Short-term implications of analogy and explicit instruction

To date, research regarding verbal instruction has concentrated on motor *learning* with little attention paid to the impact of instruction on motor *control*—acute, short-term adjustments to, or refinement of, skilful movement (Schorer, Jaitner, Wollny, Fath, & Baker, 2012). Although the impact of verbal instruction on robust, long-term skill development through sustained practice is a logical and necessary consideration, the reality is that many athletes are also inundated with information that is intended for *immediate* usage. In applied contexts, for instance, it is not unusual to see field event athletes in athletics receiving instruction between trials from coaches regarding technique that is meant for on-the-spot use. In rugby league, coaches may attempt to cut corners by relying heavily on verbal methods to ‘fast track’ player development (Gabbett & Masters, 2011). Across the literature, studies have often employed the temporary factor of pressure (e.g., concurrent secondary tasks) to gain insight regarding the robustness of motor learning as a function of instructional method. In reality, however, instruction itself is also often presented as a temporary factor upon which performers must immediately act. Consequently, understanding how analogy and explicit instruction not only impact long-term progress, but also immediate performance represents an important consideration, especially if researchers are going to advocate its use in professional settings (see Gabbett & Masters, 2011).

As commonplace as verbal instruction may be, however, there is limited evidence to support its use in motor control situations. In fact, a study exploring the benefits of external attention on motor control found that both non-expert and expert dart throwers generally performed better in baseline conditions than they did in any

Table 2.1. *Comparison of studies investigating differences between analogy and explicit instructions*

Study	Task	Learning trials per day (blocks × trials)	Days of learning	Pressure manipulation	Outcome measures	Participants	Mean age (SD)	Conditions	Number of rules
Schücker et al. (2013)	Golf putting	300 (6 × 50)	1	Tone judgement Prize money Peer comparison	Putt accuracy	41	21.4 (2.98)	Analogy (<i>n</i> = 20) → Explicit (<i>n</i> = 21) →	1*† 6†
Koedijker et al. (2011)	Table tennis topspin forehand	250 (5 × 50)	1	n/a	Target accuracy	29	23.4 (4.9)	Analogy (<i>n</i> = 14) → Explicit (<i>n</i> = 15) →	1 5
Schücker et al. (2010)	Golf swing	Varied	6	Tone judgement	Drive distance Drive deviation from centre	51	32.7 (12.3)	Analogy (<i>n</i> = 28) → Explicit (<i>n</i> = 23) →	30 30
Lam et al. (2009a)	Seated basketball shooting	240 (6 × 40)	2	Expert evaluation	Shooting performance Probe reaction times	24	21.9 (1.73) 21.1 (1.16)	← Analogy (<i>n</i> = 12) ← Explicit (<i>n</i> = 12)	→ 1 → 8
Lam et al. (2009b)	Seated basketball shooting	160 (8 × 20)	3	Backwards counting	Shooting performance (rated) Arm kinematics	27	21.0 (1.14)	Analogy (<i>n</i> = 9) → Explicit (<i>n</i> = 9) → Control (<i>n</i> = 9) →	1 8 0
Koedijker et al. (2007)	Table tennis topspin forehand	450 (9 × 50)	1	Prize money Backwards counting	Target accuracy Movement quality (rated)	34	21.8 (3.58)	Analogy → Explicit → Environmental focus → Movement focus →	2 14 2 1
Poolton et al. (2007)	Table tennis topspin forehand	300 (15 × 20)	1	Backwards counting	Target accuracy	28	Not provided	Analogy (<i>n</i> = 14) → Explicit (<i>n</i> = 14) →	1 6
Poolton et al. (2006)	Table tennis topspin forehand	300 (15 × 20)	1	Decision making	Target accuracy	33	20.5 (3.39)	Analogy (<i>n</i> = 15) → Explicit (<i>n</i> = 18) →	1 6
Law et al. (2003)	Table tennis topspin forehand	500 (10 × 50)	1	Audience observation	Target accuracy	28	20.4 (0.95)	Analogy (<i>n</i> = 14) → Explicit (<i>n</i> = 14) →	1 6
Liao & Masters (2001)	Table tennis topspin forehand	300 (6 × 50)	1	Backwards counting	Target accuracy	30	27.5 (4.4)	Analogy (<i>n</i> = 10) → Explicit (<i>n</i> = 10) → Implicit (<i>n</i> = 10) →	2 12 0

* Analogy instructions were accompanied by a visual demonstration. † Participants also received pictures demonstrating technique.

of the verbal instruction conditions (Schorer et al., 2012), regardless of the type of attention (i.e., internal or external) engendered by that instruction. While it is not surprising that these verbal instructions—which were all explicit in nature—impaired skilled performers, it is unexpected that they would also negatively affect the novices, as the skill-focused attention engendered by explicit information is ordinarily thought to be beneficial for learners (e.g., Beilock, Carr et al., 2002; Beilock, Wierenga, & Carr, 2002). Unfortunately, not even a single study has ever compared the effects of analogy and explicit instruction in motor control contexts; consequently, it is unclear if analogy and explicit instruction differentially affect performance in these short-term situations. For any coach or sport psychologist working with athletes, developing understanding of the immediate effects of any instruction should represent an important consideration and, consequently, an important research priority.

2.9.2. Differences in instructional volume

Throughout the analogy and explicit instruction literature, one significant methodological issue makes it uncertain whether the previously observed advantages of analogy learning arose from the *type* of instruction or the reduced *volume* of instructions compared to traditional explicit methods. In this regard, the rules for the explicit conditions in previous empirical research have typically outnumbered the single-cue analogy instructions (see table 2.1 for exact figures) by ratios ranging from 5:1 (Koedijker et al., 2011) to as high as 12:1 (Liao & Masters, 2001), even though the motor learning literature (e.g., Schmidt & Wrisberg, 2004) and many coaching guides (e.g., Mannie, 1998; McQuade, 2003; UK Athletics, 2009) advise

focusing on no more than two or three key points at any one time when teaching new motor skills. Given that part of the inspiration behind the concepts of implicit and, subsequently, analogy learning was to reduce the load on attentional resources engendered by the task instructions, it would seem not only equitable, but also necessary from an experimental perspective, to explore the impact of explicit instructions in their leanest possible configuration as well. As it is, the differences in instructional volume represent a pressing methodological and conceptual limitation of the existing literature. This imbalance in instructional volume might also explain the proclivity for explicit learners to report more task-relevant rules in follow-up questionnaires than their analogy group colleagues (e.g., Koedijker et al., 2011; Lam et al., 2009a, 2009b; Liao & Masters, 2001; Poolton et al., 2006), as they would have repeatedly viewed and performed between four to eleven additional instructional steps throughout these studies.

For a fairer comparison between these two instructional types, the number of rules or the word volume of the instructional sets should correspond between conditions. Although one study previously has, in fact, attempted to match the instructional volume of the analogy and explicit groups, the researchers inexplicably provided both groups with 30 separate instructions, likely overloading the working memory of *all* participants (Schücker, Ebbing, & Hagemann, 2010). As it stands, based on the existing body of evidence, it is difficult to establish whether the performance deficits attributed to explicit learning in the existing literature resulted from conscious processing engendered by the instruction itself, as Masters would assert, or from competition for available attentional resources.

2.9.3. Applying pressure

Part of the original rationale for employing implicit instructional methods, such as analogy learning, was that it might limit susceptibility to skill failure under pressure. Consequently, the manipulation of pressure has represented a critical consideration in many studies for evaluating the robustness or effectiveness of analogy and explicit instructional methods. Research involving the effects of pressure on movement, however, has preferred to evaluate choking interventions using contrived manipulations of pressure and distraction that are often unrealistic and disproportionate to the levels experienced in sport (Gucciardi & Dimmock, 2008; Hill et al., 2010). Unfortunately, this issue pervades the analogy learning research as well with prize money (Lam et al., 2009b), expert evaluation (Lam et al., 2009a), audience observation (Law et al., 2003), and secondary task loads—such as reverse counting (Lam et al., 2009b) and tone monitoring (Orrell et al., 2006)—representing the many task-irrelevant methods used to evaluate the quality of skills learned under both explicit and analogy conditions (see table 2.1). According to Jones and Hardy (1990), however, tasks that offer more authentic anxiety manipulations represent richer opportunities for exploring the relationships between anxiety and performance. Moreover, studies that employ ego-stressor methods manage to evoke only moderate levels of anxiety that are incommensurate with those experienced during competition (Williams & Elliot, 1999). To both enhance understanding of the differential impact of various types of verbal instruction and increase the utility of this research for those in the field, research designs ought to reflect the demands and pressures experienced within authentic performance environments. Although this may be difficult or impractical to recreate in the

laboratory for certain tasks, researchers in related areas of study have managed to do so. For instance, in two studies examining the effects of anxiety on movement and behaviour (Pijpers et al., 2005; Pijpers et al., 2003), anxiety was evoked by simply manipulating the height of their climbing task, while leaving all other aspects of the route unchanged, creating two ecologically valid—but otherwise identical—environments in each of their studies. For analogy and explicit learning studies in which performance under pressure represents a key aspect of the investigation, selecting tasks that permit more authentic pressure manipulations should likely form an important consideration of the research design.

2.9.4. Fatigue and decreased performance

Another methodological concern from the literature is the large number of learning trials performed during the acquisition phases of these studies (see table 2.1), particularly because the participants in these studies are all novices. For instance, Lam et al. (2009a) asked participants to shoot 240 basketball shots *per day* during the two-day learning phase. This quantity would prove substantial even for ordinary basketball shooting, which typically involves the legs to generate the necessary power, but this is an extraordinary amount for these beginners, as they were required to shoot from a seated position using only their arms. In the five empirical studies to use a table tennis task, the number of daily trials of the learning phase ranged from 250 (Koedijker et al., 2011) at the low end to 500 trials (Law et al., 2003) at the peak—and this was *prior* to participation in the testing phase, which included further trials. For those learners who are unaccustomed to performing similar exercises or tasks, the large volume of trials would likely exert a measurable

toll physically. Although it may be important from a scientific perspective to have participants perform as many learning trials as possible, the large quantity of trials focusing on a single skill are likely unreflective of novice learning, which could affect the nature of the results and, by extension, the application of these findings to real-world situations.

A more pressing issue, however, is that recent research indicates that concurrent cognitive demands may also negatively impact motor performance. For instance, Mehta and Agnew (2011) found that performing the Stroop colour word test (Stroop, 1935) during an upper arm task resulted in decreased EMG activity in mean anterior and posterior deltoid muscles compared to control conditions, especially at higher physical exertion levels. Likewise, Mehta and Parasuraman (2014) found that counting backwards during a hand-grip task resulted in significantly lower blood oxygenation in the bilateral prefrontal cortex upon exhaustion than in the control condition. The findings of these studies suggest additional cognitive demands may negatively influence physical performance, which has significant implications for the previous research in analogy and explicit learning. As the explicit conditions throughout the literature had significantly greater instructional loads, as discussed in section 2.9.2, it is possible that they were also experiencing greater physical fatigue as well, harming performance relative to their analogy counterparts.

2.9.5. Participant ages

To date, studies comparing analogy and explicit instruction on motor skill learning and performance have only investigated their effects on adult learners (see

mean age section in table 2.1). Recent research, however, suggests that aspects of motor skill learning differ in adolescents compared to adults. For instance, Sullivan, Kantak, and Burtner (2008) found that children who received knowledge of results (KR) after every response (i.e., 100% frequency) performed better than those who received feedback after only 62% of trials in an arm movement task, whereas the opposite pattern was observed in adults for the same task. Research also indicates that adolescents possess unique information-processing capabilities (Pollock & Lee, 1997; Wade, 1976) and demonstrate differences in cognitive processes—such as selective attention (Tipper, Bourque, Anderson, & Brehaut, 1989) and verbal learning (Yuzawa, 2001)—which may contribute to differences between adolescents and adults with respect to motor learning (Sullivan et al., 2008). A key issue, according to Sullivan (2008), is that these cognitive differences may also limit the ‘generalisability of motor learning and performance principles derived primarily from young adults to children’ (p. 721). As analogy and explicit learning involve both movement and cognitive aspects, it will be important for research to begin investigating how age might moderate the effects of each instructional type. Following this line of research is also meaningful because adolescents better reflect the athletes and students that would be learning new movement skills in the field. Admittedly, however, there may be significant challenges or constraints in engaging adolescents in research that could render their recruitment difficult. Nevertheless, it is important that research look to overcome these challenges to gain greater insight.

2.9.6. Longitudinal effects and implications for experts

Although this thesis is not outwardly interested in investigating the effects of

analogy and explicit instruction in experts, the inspiration for the development of implicit instructional strategies—such as analogy—rests in their potential to limit choking in skilled performers. Consequently, the long-term prospects for using analogy and explicit instruction do represent an important consideration when teaching novices, especially for applied practitioners. While there are certainly challenges in administering a well-controlled between-groups study that follows analogy and explicit learners from novices to well-seasoned experts, a few studies in related areas have attempted to gain some insight in this regard with some longitudinal investigations. For instance, Maxwell et al. (2000) compared the performance of implicit and explicit learners in a delayed retention test one year after initially learning a golf-putting task. Although the implicit learners had reported significantly fewer verbal rules than their explicit learning counterparts during learning, there were no differences in performance between the groups a year later. This corresponds with the results of Poolton et al. (2007a) in their one-year delayed retention test in a rugby-passing task, which the researchers attributed to a ‘decay’ of rule-based knowledge regarding the skill. In another study by Schücker et al. (2010), novice golfers learned a golf swing over the course of six weeks using either analogy or explicit instructions and, again, there were no statistically significant differences observed between conditions. It should be noted, however, that the surprisingly large instructional volume (30 instructions for each condition) and lack of standardisation in the design (e.g., practice was not standardised across participants and free practice was permitted) raise serious questions regarding the validity of the results derived from this study. At the moment, support regarding the long-term advantages and

stability of analogy learning remain scant, although this could simply be due to the paucity of investigations.

To date, few studies have considered the impact of any implicit methods on expert performers. One study by M. Reid and Giblin (2015) did investigate the use of an analogy intervention to promote movement alteration in elite, internationally ranked junior tennis players, but this research was biomechanically oriented and did not include any other instructional conditions for comparison. The absence of an explicit or control condition may be due to ethical concerns, because of the demonstrated association between explicit information and performance breakdown under pressure, creating significant challenges for studies involving elite performers. While there were kinematic changes to the participants' serves over the course of the study compared to baseline conditions (increased range of motion of trunk and peak angular velocity during the serve stroke, and increased leg drive during drive phase), it is unclear whether these differences were unique to analogical instruction. Consequently, the implications for elite performers in real-world settings remain uncertain. While outside the scope of this thesis, furthering knowledge regarding instructional techniques for refining expert performance—whether through analogy or other means—represents an important consideration for sport psychologists and coaches.

2.9.7. Moving beyond outcome measures

Another shortcoming of previous research is that the current literature has largely failed to consider the impact of analogy or explicit instruction on movement itself. As Pijpers et al. (2003) noted, the effects of various factors—such as anxiety

or pressure—on movement mechanics represent a primary concern of athletes, coaches, physical educators, and sport psychologists in the field. Skill instruction should also be one of these factors under consideration; however, to date, its impact on movement mechanics has remained largely unexplored. The overreliance on performance outcomes—and inattention to movement patterns—for evaluating the effectiveness of verbal instructional methods seems curious, as sport psychologists typically encourage their clients to emphasise processes rather than outcomes (Andersen, 2000). As the goal of any sport psychology intervention is subjectively defined and varies between individuals (Roberts & Kristiansen, 2010), using such uncompromising measures of success also misrepresents the realities of applied work, especially as not all sporting performances are evaluated in purely objective, outcome-based terms. For instance, in sports such as synchronised swimming and rhythmic gymnastics, the quality of the movement itself represents the foremost consideration for athletes, coaches, and, by extension, sport psychologists. Moreover, researchers have also highlighted the need to incorporate biomechanics and motor learning into sport psychology research to enhance our understanding of learning principles (Buttfield, Ball, & MacMahon, 2009).

Unfortunately, to this point, few studies have even considered the impact of analogy instruction on movement mechanics and only a single study has ever empirically measured and compared the effects of analogy and explicit instruction on movement. In that one study, Lam et al. (2009b) found no evidence of any significant kinematic differences in a seated basketball-shooting task with respect to instructional type. The similarities in kinematic parameters were unexpected, especially as even similar performance outcomes are produced by a nearly infinite

number of different movement possibilities (Glazier, 2011). One possible explanation is that the simplified basketball-shooting task reduced kinematic differences between instructional types or even individuals. To counter this, future studies could incorporate more complex motor skills that typify real-world sports and movement skills. A more pressing issue, however, may be the absence of a clear theoretical framework or biomechanical model from the predominant cognitive perspective to guide the kinematic analyses and to contextualise any potential findings from those analyses, as the mere existence of movement differences is not necessarily inherently meaningful. For instance, in the study by Lam et al. (2009b), it is unclear what any observed differences in maximum shoulder flexion would represent with respect to instructional type, the task, or movement in general. This is not to say that such exploratory kinematic analyses do not possess value, but that future research may benefit from incorporating or adopting other conceptual frameworks for making sense of any findings. In fact, a number of researchers have questioned the purely descriptive nature of sport science research, calling for more analytical approaches for conceptualising and evaluating movement (e.g., Elliot, 1999; Glazier, Davids, & Bartlett, 2003; Nigg, 1993). At present, the prevailing unidimensional interpretation of performance, perhaps constrained by the limitations of traditional cognitive approaches to skill learning, limits the utility and application of this previous research and must be addressed in future research to offer greater understanding to researchers, educators, and practitioners alike.

2.9.8. Moving beyond the cognitive perspective

Although it is not the intent of this chapter—or this thesis—to promote one

particular theory of skill learning and motor control over any other, it is important that relevant theoretical approaches to skill learning and motor control are considered, as these frameworks—implicitly or explicitly—can inform and guide both research and applied practice (Davids et al., 2008). Furthermore, there is need for the validation of coaching practices that are based on how performers learn, rather than assumptions regarding how a skill should be performed (Hodges & Franks, 2004). As noted in section 2.1, the self-focus explanations for choking, such as Masters' (1992) CPH, are closely linked to the customary cognitive approach to skill acquisition and it is this very cognitive approach that has subsequently guided and dominated the methodology and the course of the investigations in analogy, implicit, and explicit learning to date.

While there is empirical evidence to support elements of the cognitive frameworks, a growing number of researchers and movement scientists have criticised these approaches and their strict reliance on the central nervous system to control and manage all aspects of idealised movement. One prominent alternative approach to these traditional top-down theories is dynamical systems theory, which proposes that behaviour and movement patterns instead emerge spontaneously as consequences to internal and external variables and constraints (Hodges, Hayes, Horn, & Williams, 2005). From this perspective, human movement constitutes just one of many interacting subsystems (e.g., muscular, chemical, neuronal, hormonal; Newell, 2005) of the complex human biological system. Throughout the levels of the overall system, there are innumerable individual components—known as degrees of freedom—that interact, fluctuate, and self-organise into many possible configurations (Davids et al., 2008). While the degrees of freedom at joint space—

the controllable independent planes of motion of the joints—amount to approximately 120, the available degrees of freedom increase substantially at each subsequent level of analysis (Newell, Liu, & Mayer-Kress, 2005). For instance, the degrees of freedom at muscle and neuronal space register $>10^3$ and $>10^4$, respectively, indicating that control of the human biological system requires the coordination of millions of degrees of freedom across a multitude of levels (Newell, 1996). Although observation at the microscopic level suggests significant potential for disorder and unpredictable interactions between these many individual components, inspection at the macroscopic level demonstrates astonishingly stable patterns of behaviour (Button et al., 2008; Kauffman, 1993, 1995). For the movement system specifically, these stable patterns—termed attractors in open systems parlance—represent robust, functional coordination tendencies, such as the antiphase pattern in locomotion, that are not easily destabilised (Button et al., 2008).

According to Button et al. (2008), the emergence of these consistent states of order is defined by organismic (e.g., height, weight, muscle mass, motivation, self-efficacy) task (e.g., rules, equipment, playing surfaces), and environmental constraints (e.g., weather, temperature, gravity, air pressure) that can both limit and enable possible movement trajectories. For instance, the physical characteristics of performers themselves—categorised as organismic constraints—can facilitate or constrain the available movement possibilities. In this regard, a larger handspan will afford a pianist movement configurations that are unavailable to those with smaller handspans. Similarly, the rising height of the bar in a high jump competition—which constitutes a physical task constraint—may also limit the number of functional coordination patterns available to the human movement system. While lower heights

afford performers greater freedom with regard to movement possibilities, increasing the bar height constrains the phase space—the available hypothetical coordination possibilities—and, consequently, decreases the number of functional movement configurations that will permit successful bar clearance. The interaction of these organismic, task, and environmental factors constrains the human movement system, stimulating the emergence of coordinated movement.

For Gibson (1979), humans also directly perceive characteristics or qualities of the environment and the actions or behaviours that these qualities might afford them. This concept—known as affordance—comprises both objective (e.g., a chair invites sitting) and subjective (e.g., someone must possess sufficient limb length or height to enable sitting) properties that demonstrate the 'complementary relationship' between individuals and their environment (Button et al., 2008). According to Gibson (1979), many psychologists incorrectly assume that individuals perceive the *qualities* of the objects in our environment, when individuals are actually perceiving the *affordances* of those surrounding objects.

For sport psychologists, specifically, the key benefit of incorporating elements of dynamical systems theory is that it offers a relevant theoretical foundation for conducting performance-oriented research, because of its interdisciplinary approach to coordination and motor control (Glazier, Davids, and Bartlett 2002, 2003). In particular, the dynamical systems approach provides a framework for measuring, understanding, and evaluating movement learning and performance, emanating from Bernstein's (1967) proposed universal motor learning solution. Recognising the multitudinous degrees of freedom that compose the human biological system, Bernstein hypothesised that there were far more joint positions and configurations

than necessary capable of achieving any desired movement solution. Whilst skilled performers may be able to harness the many available degrees of freedom to achieve a functional coordination solution, Bernstein (1967) proposed that novices must initially reduce the number of degrees of freedom by forming fixed muscle–joint linkages in the periphery (i.e., away from the joint centres). This ‘freezing’ permits learners to control those few degrees of freedom most necessary for the movement by constraining the motor system and, consequently, simplifying control. With continued practice, degrees of freedom are released as the rigid muscle–joint couplings become task-specific coordinative structures that can utilise both internal and external forces for enhanced movement economy and efficiency (Bernstein, 1967; Davids et al., 2008; Newell, 1991). From this perspective, performance eventually comes to rely on the linkages of only a few key, more manageable degrees of freedom, exploiting advantageous kinematic and energetic impulses of the movement, environment, and task. According to Bernstein, however, under stressful or anxious conditions, expert performers may regress to the freezing strategy that typifies novice performance in order to simplify movement control, consistent with similar predictions from Masters’ CPH.

Empirically, and of particular interest for this thesis, this process of freezing and freeing degrees of freedom should be characterised by increasing variability within and across joints and by decreasing dependency between joints (Vereijken, van Emmerik, Whiting, & Newell, 1992). Vereijken et al. (1992) provided evidence in this regard, as the standard deviation around the mean for the ankle, knee, and hip joints of uninstructed novices increased with learning in a ski-simulator task, while cross correlations between those joints decreased. Offering further support for

Bernstein's predictions, Pijpers et al. (2003) observed that participants demonstrated stiffer, less fluent movement mechanics in a climbing task under anxious conditions (higher altitude) than under unstressed conditions (lower altitude). These predictions offer guidance for objectively measuring and evaluating learning and movement that is not provided by the cognitive approaches to skill acquisition, which has, to date, prescribed descriptive methods of evaluation with limited theoretical direction.

Newell and Vaillancourt (2001) have argued, however, that this process of freezing and freeing degrees of freedom may, in fact, depend on the task and the constraints of that task. In this regard, recent evidence has shown variable patterns in joint variability and cross correlations that conflict with Bernstein's predictions (e.g., Hodges et al., 2005; Ko, Challis, & Newell, 2003). According to advocates of the nonlinear pedagogical perspective—an instructional approach that emanates from dynamical systems theory (Renshaw, Davids, Chow, & Shuttleworth, 2009)—the reduction of the large number of degrees of freedom may actually depend on a large number of constraints that are individual to the learner, including verbal instruction regarding the task (Komar, Chow, Chollet, & Seifert, 2014). By examining the variability between joints in analogy and motor learning studies, insight could be achieved regarding the nature of movement during motor learning and its interaction with differential verbal instructional sets in line with the hypotheses of Bernstein and Masters and beyond what has been possible by exploring these concepts within a purely cognitive framework.

2.9.9. Task choice

Up to now, there has been limited task variety in the analogy and explicit learning literature with the majority of the research concentrating on modified table tennis tasks (see table 2.1). Interestingly, the studies that have attempted to extend the investigation beyond derivations of table tennis have failed to produce findings that uniformly lend support to analogy learning. For instance, Lam et al. (2009a, 2009b) did not find significant differences between analogy and explicit learners in basketball-shooting performance, while Schücker, Hagemann, and Strauss (2013) found that both analogy and explicit participants performed similarly under pressure and dual-task conditions in a golf-putting task. It should be noted, however, that there were serious methodological concerns in the Schücker et al. (2013) study, as researchers presented both conditions with multiple forms of instruction (i.e., verbal, illustrative, and demonstrative) and applied three simultaneous pressure manipulations (i.e., tone judgement, prize money, and peer comparison), so the findings from this paper should be considered with a degree of caution. Nonetheless, continuing to extend the study of analogy and explicit instruction beyond table tennis should remain an important consideration for practitioners in the field. As research has already suggested that the nature of motor learning might vary with respect to the task (e.g., Hodges et al., 2005; Ko et al., 2003), research should also explore the possibility that properties of the task could also interact with the type of instruction given.

2.10. The current thesis

While the literature is suggestive of advantages for analogy instruction over traditional explicit methods, there are several significant limitations and gaps in knowledge that pervade this research, as identified throughout this chapter. To better inform applied practitioners, these points must be addressed while building upon the foundations of the previous research. In particular, issues regarding instructional length, motor control, and movement measurement represent several important lines of enquiry based on both addressing methodological issues and informing evidence-based practitioners. As such, this thesis aimed to further examine analogy and explicit instruction by investigating and appraising their differential effects on movement and performance.

Chapter 3. The acute effects of verbal instruction on performance

Chapter Aims

In this chapter, the differential effects of analogy and explicit instruction on motor control are investigated. Employing a within-subjects design, adult participants performed a dart-throwing task under baseline, analogy, and explicit instruction conditions in the presence and absence of knowledge of results (KR). Performance and movement in the task were evaluated using accuracy, kinematic, and joint variability measures. As the first study to examine the acute effects of analogy and explicit instruction, the findings and their significance are discussed from both theoretical and applied perspectives.

3.1. Introduction

As discussed in chapter 2, research involving verbal instructions has predominantly focused on early stage motor *learning* with little attention directed toward its effects on motor *control*—acute adjustments to, or refinement of, skilful movement (Schorer et al., 2012). In this research, studies have typically employed the temporary factor of pressure (e.g., dual-task or evaluative conditions) to evaluate and measure motor learning as a function of instructional method. In real-world learning, training, and competitive environments, however, it is the instruction itself that is most often presented as the temporary factor upon which students, learners, and skilled performers must instantly act. In this regard, it is not uncommon for physical educators or coaches across many sports and skill levels to rely on the spoken word to direct their players in training and competition. For instance, Gabbett and Masters (2011) noted that the constraints of time, expense, and injury often

compel coaches in rugby league to attempt to accelerate player development by reverting to explicit verbal methods of instruction or by providing inappropriate amounts of feedback. For practising sport psychologists, who will work with performers and coaches of many skill levels and backgrounds, it is important to understand the implications of such methods on performance, both in acute and long-term contexts. Unfortunately, however, there is currently limited empirical information to guide practitioners regarding the capacity of performers to make immediate use of verbal information in motor control situations.

Although the concepts of motor learning and motor control can appear, at times, abstract and indistinct (Schmidt & Lee, 1999), research findings reveal that they are, in fact, separate and unique concepts in their own right. For example, the external, effect-oriented instruction that is associated with enhancements in novice motor learning (e.g., Wulf, Gaertner, McConnel, & Schwarz, 2002) may also disrupt performance in acute motor control situations (Schorer et al., 2012). In this regard, in a dart-throwing study by Schorer et al. (2012), instruction of nearly any kind—whether internally or externally focused—was detrimental to immediate performance for both experts *and* novices compared to control conditions, except in one instance (experts who received external focus instructions with KR). These findings are consistent with expectations for elite performers, who typically rely on automatised processes, but it is particularly striking, given the prevalence of verbal instruction throughout sport and physical education, that the novice participants were also unable to exploit the verbal information to their advantage. The instructions across all groups in this study, however, were strictly explicit in nature (e.g., concentrate on the release of the dart), so it is difficult to determine whether it was the verbal

instruction itself or the type of verbal instruction that accounted for the drops in performance from the baseline conditions. As analogies are thought to facilitate implicit motor learning and curb internally focused movement control, it was of interest to determine whether all verbal instruction acutely affects motor control in the same manner or if it varies as a function of instructional type.

3.1.1. The current study

The present study sought to investigate the acute effects of verbal instruction on motor control as a function of instructional type in a dart-throwing task. The primary aim was to determine the immediate, short-term effects of analogy and explicit instruction and their implications for both movement and performance outcomes. In all cases, participants were asked to use *only* the technical instructions provided to them to throw the darts as close to the centre of the dartboard as possible. Because post-performance results and feedback are generally acknowledged to be largely responsible for trial-to-trial changes in motor behaviour (Perkins-Ceccato, Passmore, & Lee, 2003), the dartboard was immediately occluded for half of the throws for each instruction type to prevent any knowledge of results (KR). The absence of KR in these instances was intended to strengthen the effect of the instructions and prevent deliberate changes in technique based on results from previous trials (i.e., hypothesis testing), which is associated with the accumulation of explicit knowledge (Maxwell, Masters, & Eves, 1999). Because KR is not ordinarily withheld in either learning or competitive situations, however, participants were permitted to see their results for the other half of the throws in order to better represent real-world conditions. Consequently, participants threw competition darts

at a regulation-sized dart board in accordance with the rules of the World Darts Federation (2014) in a total of six different conditions: baseline without KR, baseline with KR, analogy without KR, analogy with KR, explicit without KR, and explicit with KR. As in the study by Winter and Collins (2013), participants first performed the control condition—with and without the availability of KR—followed by the remaining conditions, which were counterbalanced in order to control for biases in presentation order (Hinkelmann & Kempthorne, 2008).

As one of the main aims of this thesis overall is to understand the differential impact of these instructional types on movement itself, kinematic measures were employed alongside accuracy measures to examine movement mechanics with respect to condition. Of particular interest was the effect of instruction on joint variability, particularly with regard to Bernstein's (1967) predictions for the freezing and freeing of degrees of freedom, as discussed in the literature review in section 2.9.8. Additional kinematic measures, such as maximum elbow flexion and angular velocity were included to facilitate comparison with previous research involving dart throwing (e.g., Lohse, Sherwood, & Healy, 2010).

3.2. Method

3.2.1. Participants

Twenty healthy adult participants (mean age = 23.2 years, $SD = 7.35$, 14 males and 6 females) with no previous formal experience in dart throwing volunteered for this study. All participants were right handed and provided informed consent before commencing the study. The research was conducted in accordance with the research guidelines set forth by the British Psychological Society (BPS) and met the criteria

for level 1 ethical clearance according to the University of Edinburgh School of Education ethics committee.

3.2.2. Apparatus and task

Participants performed the task in a purpose-built sport science laboratory using standard 24 g darts and a 1.5 m × 1.5 m wooden dartboard placed at regulation height (1.73 m). All trials were completed from a distance of 2.37 m from the dartboard, which was clearly marked using white tape on the red rubber laboratory flooring. Colour-coded concentric circles, modelled after B. McKay and Wulf (2012), were painted directly onto the board to indicate the 11 scoring zones, which were each of equal radial width, ranging from 1 at the outermost area of the board to 11 for the bull's eye itself. Any throws that completely missed or failed to stay on the board were not awarded any score.

The aim for the participants was to achieve high scores by throwing the dart as close to the centre of the dartboard as possible on each trial. For the three experimental conditions that did not allow KR, a 40 cm × 40 cm cardboard cutout was placed in front of participants immediately following each trial to occlude vision of the dartboard and restrict the accumulation of knowledge regarding throwing results (B. McKay & Wulf, 2012). In a pilot study to evaluate this method of occlusion, participants were only able to correctly identify in which scoring zone their dart had landed on 20% of trials. The effectiveness of this KR-blocking measure was then periodically monitored throughout the course of the study by asking three different participants to perform an additional set of trials upon completion of all other tasks relating to the research. The results of these additional

checks indicated similar levels of accuracy ($M = .25$, $SD = .08$) compared to the pilot tests.

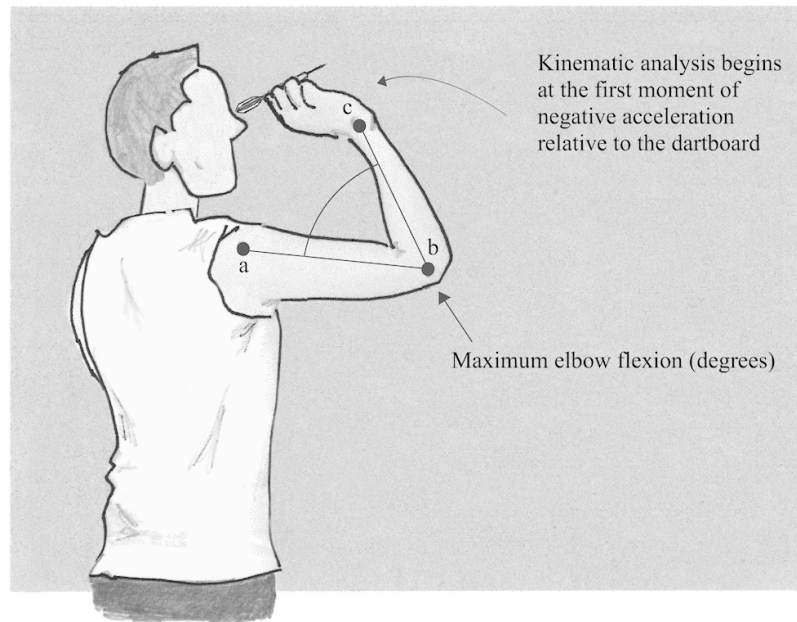
A video camera (Canon MD101), positioned at an angle of 90° to the plane of the dart throw, recorded digital footage of each trial in the sagittal plane at 50 Hz for subsequent movement analysis. In line with previous investigation (Lohse et al., 2010), contrasting anatomical markers were placed on the acromion process, the lateral epicondyle, and the styloid process of the throwing arm (depicted in figure 3.1 on p. 52) to facilitate automated tracking and analysis with the APAS three-dimensional motion analysis system (Ariel Performance Analysis System; Ariel Dynamics, Inc.; San Diego, CA, USA).

3.2.3. Motivation manipulation

To try to match the personal relevance and motivation for each throw for the participants in line with the effort and consideration that athletes might approach their own performances, cash prizes were offered to the top three total scores across all competitors (£30, £20, and £10). To be eligible for the prizes, participants were informed that they must complete the task in its entirety (i.e., perform all trials and complete all of the paperwork) and follow directions throughout. As the specific aim of this study was to explore the acute effects of information on motor control in sport, a contrasting low-motivation condition was not included.

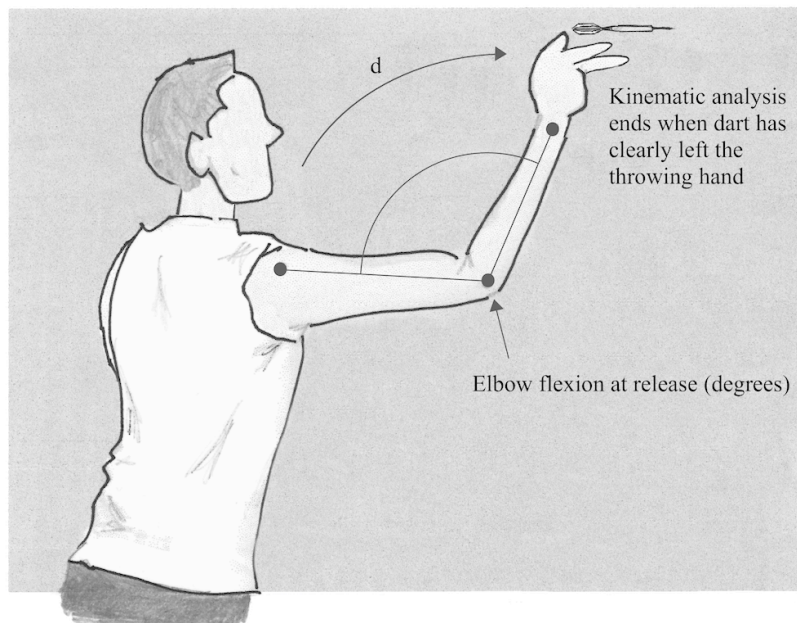
3.2.4. Procedure

Attending individually, participants performed the dart-throwing task under six different experimental conditions, as shown in table 3.1 (p. 53). For each of the



Contrasting anatomical markers for the kinematic analyses were placed on the:

- a) Acromion process
- b) Lateral epicondyle
- c) Styloid process



d) Angular velocity calculated by dividing the difference between elbow angle at extension (release) and at maximum flexion by the time.

Figure 3.1. Figure depicts the throwing technique and key concepts relevant to the kinematic analyses of the task. Top illustration shows placement of anatomical markers and measures for moment of maximum flexion (retraction). The bottom displays kinematic measures of interest at the time of release (extension). Figure inspired by similar model from Lohse et al. (2010).

conditions, data were collected in single sets comprising 12 trials. Participants were informed that they would receive periodic instruction throughout the study and that their aim was to use the provided information to ‘throw the darts as accurately as possible at the bull’s eye’. The two baseline conditions—baseline without KR and baseline with KR—were performed at the start of the task in all instances, while the remaining four conditions were counterbalanced across all participants using a Latin square design to control for possible order effects (Schorer et al., 2012). Modelled after Wulf et al. (2002), participants received instructions in each condition before the first throw and then again after every three throws (i.e., before trials 1, 4, 7, and 10), except in the baseline conditions in which participants were only instructed at the start to ‘throw at the bull’s eye’ (Schorer et al., 2012). Participants were asked to listen and repeat the given instruction in each instance to ensure that the information had been heard correctly. A detailed list of all instructions is provided in table 3.2 (p. 54). Prior to beginning the experimental conditions, participants were afforded a single set of 12 practice trials to familiarise themselves with the task. Once participants had performed all trials, they were asked to rate their perceived level of motivation on a scale ranging from 0 to 10 (Schorer et al., 2012).

Table 3.1. *Experimental Conditions*

1.	Baseline
2.	Baseline without KR*
3.	Analogy
4.	Analogy without KR*
5.	Explicit
6.	Explicit without KR*

*KR (knowledge or results) blocked following throw

Table 3.2. *Instructions for the Experimental Conditions*

Condition	Instructions
Baseline	Throw at the bull's eye
Analogy	<p>Grip the dart as if it were a crisp/chip</p> <p>Move your arm like a catapult to throw the dart</p> <p>Follow your hand all the way through the throw like a basketball player finishing his shot</p> <p>Imagine that your body has frozen into place and only your throwing arm can move</p>
Explicit	<p>Hold the dart with a relaxed, yet firm grip</p> <p>Leading with your elbow to start, move your hand back with the dart, and, in one motion, throw the dart toward the board</p> <p>As you complete your throw, extend and point your fingers toward the target</p> <p>Keep your body, legs, and left arm stationary throughout the throw and let your right arm do all the moving</p>

3.2.5. Statistical analyses and dependent measures

This study employed a 3×2 (Instructional Type \times KR) within-subjects design, comprising outcome (throwing accuracy), performance (kinematics), and psychological measures. Any violations of the assumption of sphericity were adjusted using Greenhouse-Geisser procedures. The total number of points scored per condition was used as the primary measure of throwing accuracy. To assess joint variability with respect to instructional type, the standard deviation around the mean was calculated for the elbow joint for all throws. Prior to analyses, the standard deviation data were transformed into coefficients of variation (CV) to eliminate the mean differences between individuals (James, 2004; Lam et al., 2009b). Maximum elbow flexion, elbow flexion at the moment of dart release, throwing time, and angular velocity (from the moment of maximum elbow flexion to the release of the dart) constituted the additional kinematic measures, in accordance with Lohse et al. (2010). As illustrated in figure 3.1 (p. 52), digitisation for each throw began at the first moment of negative acceleration for the dart—relative to the dartboard—through to the release of the dart, following a positive acceleration (Lohse et al., 2010). Because the throwing movement for one participant deviated from the sagittal plane (i.e., used a ‘side-arm’ throwing style) for four of the six conditions, none of her data was included in the kinematic analysis. Five other participants also had throws in which they temporarily adopted a side-arm technique, largely arising from the instruction to ‘move your arm like a catapult’ (see table 3.2 on p. 54), but in these instances only those specific trials were excluded. Motivation was assessed using self-reported ratings based on the methods of Schorer et al. (2012). All effects herein reported as significant at $p < .05$.

3.2.6. Digitising accuracy and precision

To evaluate digitising accuracy, a moving 175 mm rigid segment was digitised using the same method as the participant analyses (Salter, Sinclair, & Portus, 2007; Wormgoor, Harden, & Mckinon, 2010). Results indicated that the mean reconstructed length of the segment was $176 \text{ mm} \pm 0.75$ with a mean error of 1 mm (0.6%), in line with results from both Salter et al. (2007) and Wormgoor et al. (2010). To assess digitising precision (Challis, 1997; Coleman & Rankin, 2005), a single throwing trial was digitised six separate times and, from these data, typical error was then calculated (Hopkins, 2000). Repeated digitisation yielded a typical error of $\pm 0.09^\circ$ for the angle of the elbow joint.

3.3. Results

3.3.1. Accuracy scores

A two-way ANOVA revealed a significant main effect of instructional type on dart-throwing accuracy, $F(1.443, 27.413) = 15.060$, $p < .001$, $\eta_p^2 = .44$. Contrasts indicated that scores for the baseline conditions surpassed those from both the analogy, $F(1, 19) = 20.445$, $p < .001$, $\eta_p^2 = .52$, and explicit conditions, $F(1, 19) = 44.981$, $p < .001$, $\eta_p^2 = .70$, respectively. There was also a significant main effect of KR on throwing accuracy scores, $F(1, 19) = 12.040$, $p < .005$, $\eta_p^2 = .39$, with performances under KR conditions ($M = 78.5$, $SD = 14.0$, $SE = 2.3$) exceeding those scores achieved without the benefit of KR ($M = 70.4$, $SD = 17.1$, $SE = 3.0$). Cumulative accuracy scores as a function of condition are presented in figure 3.2 (p. 58)

3.3.2. Joint variability

To investigate the effect of instructional type on joint variability, a two-way ANOVA was run on CV data. Prior to analysis, the CV figures were square root transformed to ensure the normality of the data. Analysis showed a significant effect for instructional type, $F(1.348, 24.257) = 15.947, p < .001, \eta_p^2 = .47$, with pairwise comparisons revealing that joint variability for the baseline conditions, $M = .60, SD = .06, SE = .01$, was significantly less than either the analogy, $p < .005$, or explicit conditions, $p = .001$ (see figure 3.3). The variability between joints, however, for the analogy, $M = .63, SD = .06, SE = .01$, and explicit instruction conditions, $M = .63, SD = .08, SE = .01$, was remarkably similar, $p = .702$. Although joint variability was higher on average for all three of the instructional types when knowledge regarding results was available, these differences were not statistically significant within subjects, $F(1, 18) = 3.103, p = .095$.

3.3.3. Maximum elbow flexion

Analysis indicated a significant main effect of instructional type on maximum elbow flexion, $F(1.159, 20.864) = 8.790, p < .01, \eta_p^2 = .33$, with contrasts revealing that the degree of maximum flexion for the baseline conditions was significantly greater than either the analogy, $F(1, 18) = 9.520, p < .01, \eta_p^2 = .35$, or explicit conditions, $F(1, 18) = 9.047, p < .01, \eta_p^2 = .33$. The results with respect to condition for maximum elbow flexion are displayed in figure 3.4 (p. 60).

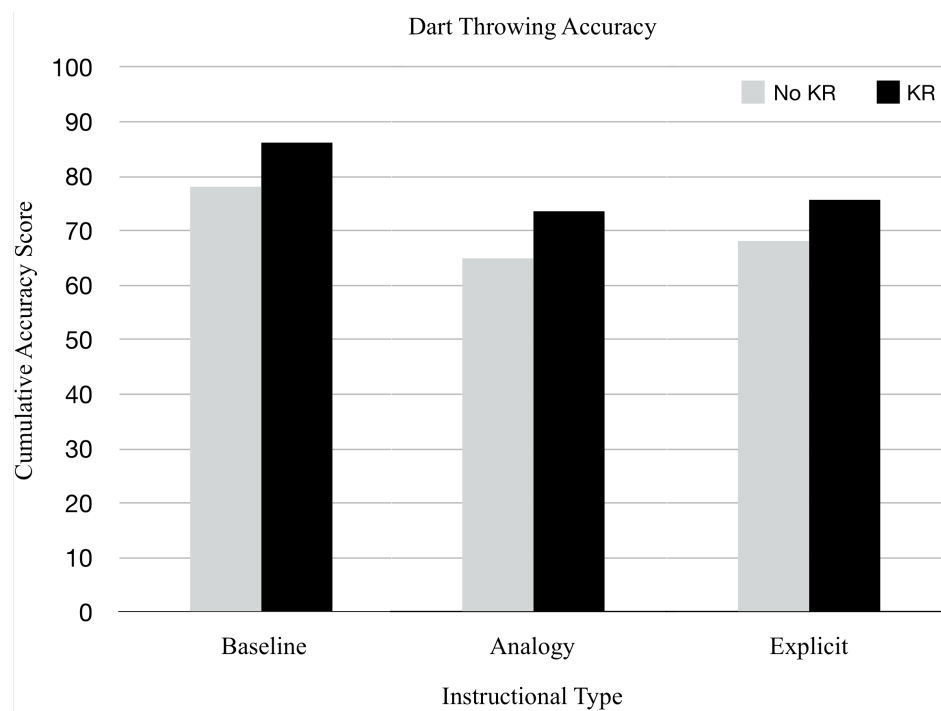


Figure 3.2. Cumulative accuracy scores averaged across participants for the six experimental conditions.

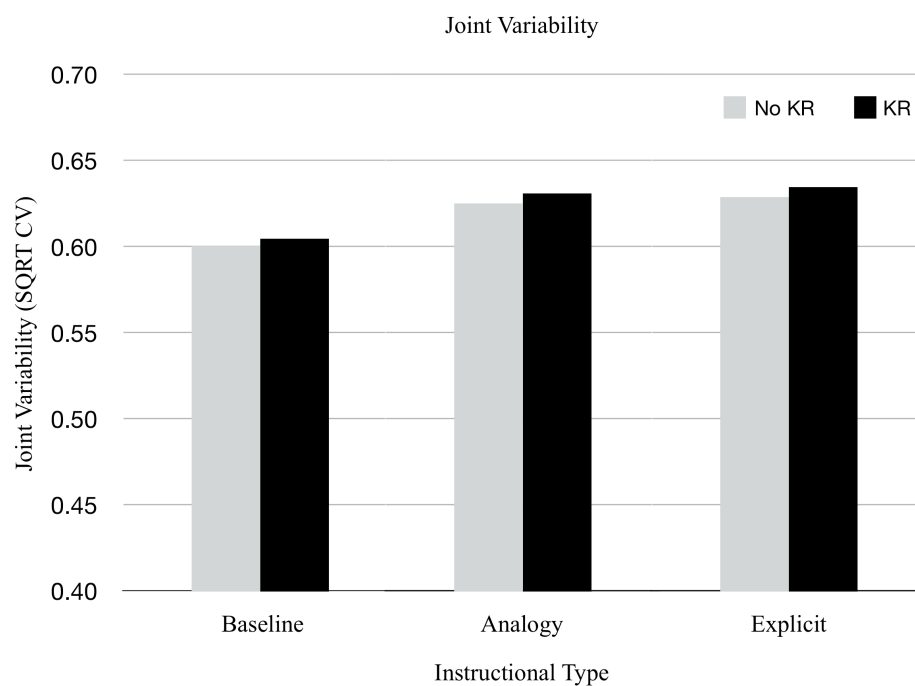


Figure 3.3. Mean square root transformed CV values averaged across participants for the six experimental conditions.

3.3.4. Elbow angle at release

Unlike the results for elbow angle at maximum flexion, the elbow angles at extension (shown in figure 3.5) did not significantly differ between conditions, $F(1.540, 27.725) = .055, p = .907, \eta_p^2 = .003$.

3.3.5. Angular velocity

There was a significant main effect of instructional type on angular velocity, $F(1.264, 22.760) = 8.804, p < .005, \eta_p^2 = .328$. In the baseline conditions, angular velocity ($M = 407.6, SD = 89.0, SE = 20.2$) significantly surpassed the figures for both the analogy, $F(1, 18) = 11.123, p < .005, \eta_p^2 = .38$, and explicit conditions, $F(1, 18) = 7.601, p < .05, \eta_p^2 = .30$. These data are presented in figure 3.6 (p. 61).

3.3.6. Throwing time

For throwing time, analysis revealed a significant main effect of instructional type, $F(1.273, 22.920) = 14.749, p < .001, \eta_p^2 = .45$. Throwing times were significantly longer for the analogy, $F(1, 18) = 21.272, p < .001, \eta_p^2 = .54$, and explicit conditions, $F(1, 18) = 12.517, p < .005, \eta_p^2 = .41$, compared to baseline performance ($M = .15, SD = .04, SE = .01$). The data for throwing time with respect to condition is shown in figure 3.7 (p. 61).

3.3.7. Motivation

In line with previous research from Schorer et al. (2012), participants reported an average level of motivation of 7.4 ($SD = 1.4$).

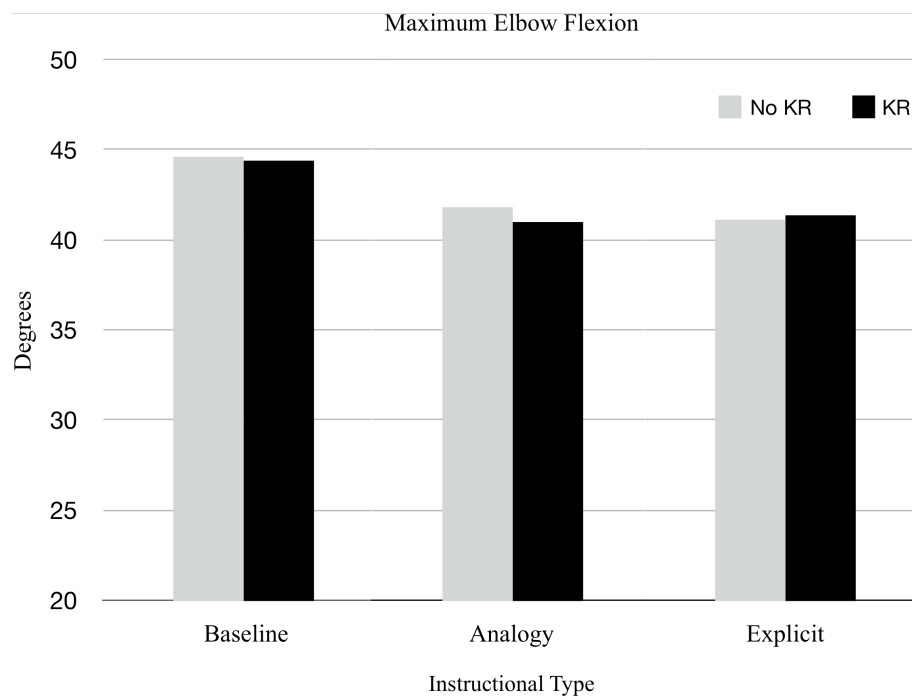


Figure 3.4. Mean maximum elbow flexion averaged across participants for the six experimental conditions.

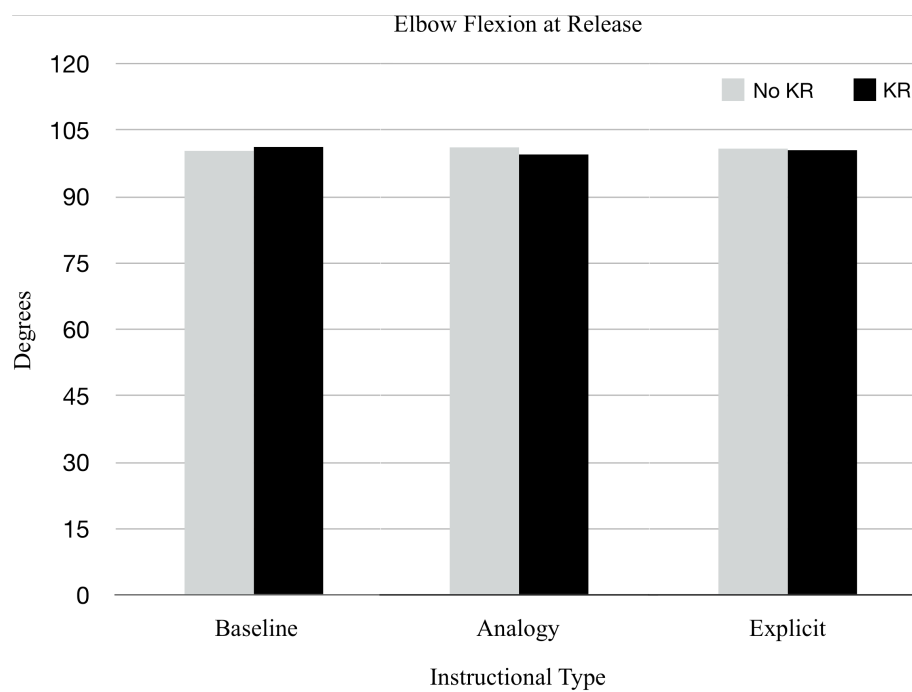


Figure 3.5. Mean flexion angle of the elbow at the time of release averaged across participants for the six experimental conditions.

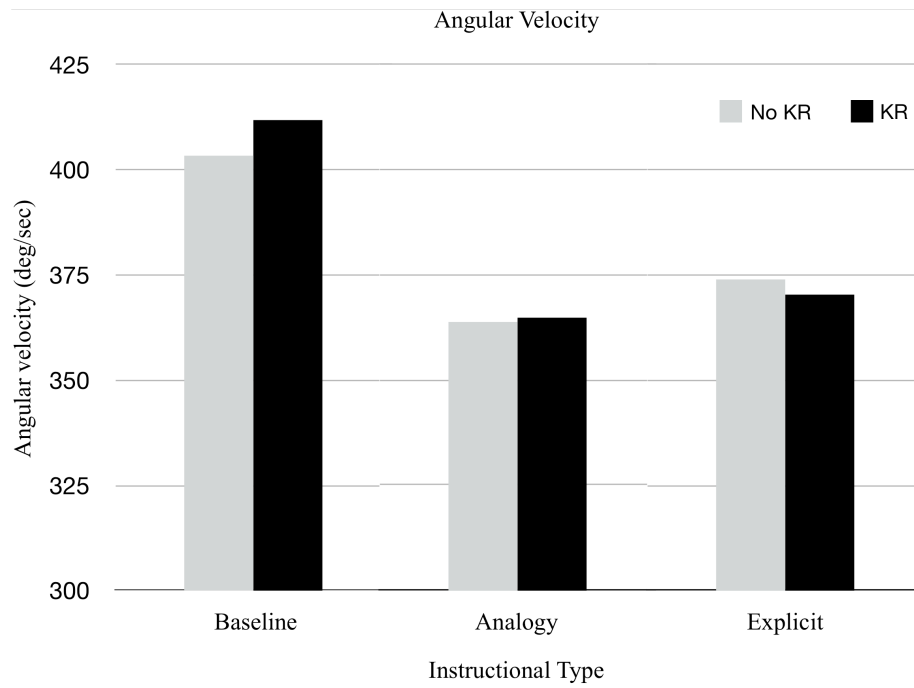


Figure 3.6. Mean angular velocity averaged across participants for the six experimental conditions.

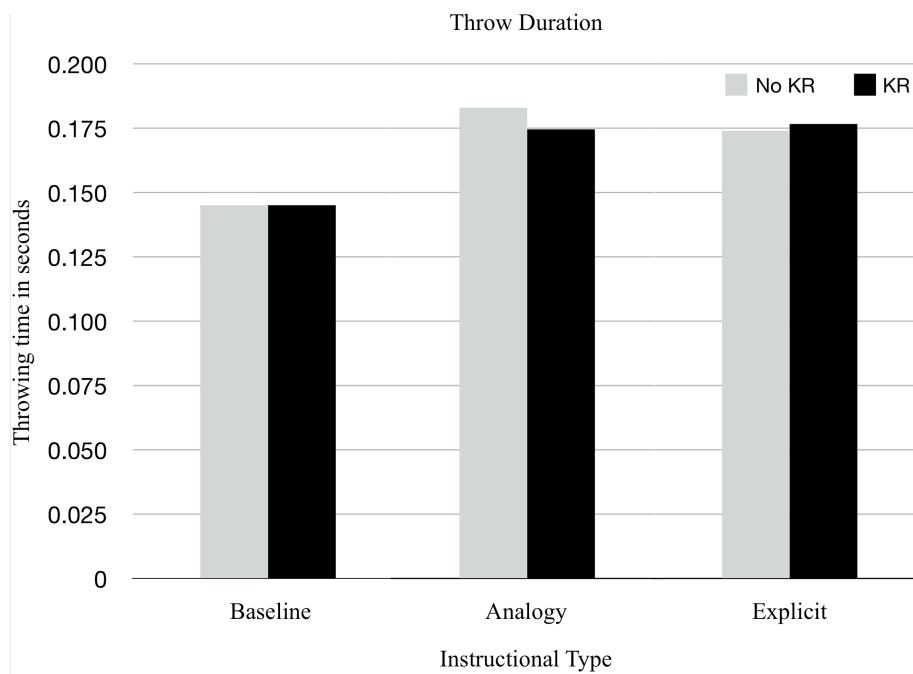


Figure 3.7. Mean throwing time averaged across participants for the six experimental conditions.

3.4. Discussion

The primary aim of the study was to determine the immediate, short-term impact of analogy and explicit instruction on movement and performance outcomes. Results indicated that any type of verbal instruction—whether analogical or explicit—was associated with significantly poorer throwing accuracy compared to baseline conditions, largely corresponding with the findings of Schorer et al. (2012). The kinematic data also revealed that participants demonstrated significantly more elbow joint variability, significantly less elbow flexion at retraction, significantly slower angular velocity, and significantly longer throwing times in the verbal instruction conditions compared to the baseline conditions, regardless of the presence or absence of KR. These findings suggest that verbal information—in the short term—leads to slower, more deliberate, and more variable movement with negative implications for performance.

While an association between performance impairment and explicit instruction would be expected for experts, the finding that *any* instruction at all disrupted performance for inexperienced performers has potentially far-reaching implications for those involved in youth sport and physical education, especially given the prevalence of verbal instruction in the field and the support for analogy instruction in the literature. In light of the findings of this study and the research of Schorer et al. (2012), coaches, physical educators, and sport psychologists may need to reconsider their use of verbal guidance in performance situations. In fact, it may even be necessary to explore alternative sources of information (SOI; Reed, 1996), such as auditory, rhythmic, or haptic cues, for conveying information in such settings. To date, several case studies have provided tentative evidence supporting SOI,

demonstrating the utility of both sonic feedback for perfecting speed skating technique (Godbout & Boyd, 2010) and rhythmic SOI for stabilising movement patterns in javelin throwing (MacPherson, Collins, & Morriss, 2008), but the effectiveness and implications of these potential SOI for sport and physical education remain largely unexplored.

Although verbal instruction in this case resulted in decreased throwing accuracy, one-word verbal cues known as mood words, however, have been shown in the past to enhance sporting performance (Rushall, 1984; Rushall & Shewchuck, 1989). The reason that mood words may be effective—where analogy and explicit instructions are not—may rest in both their holistic conveyance of a whole movement—and the temporal/rhythmical properties thereof—and their concision.

Concision—in relative terms—could also partially account for the similar performances observed in this study for the analogy and explicit instruction conditions, which is at odds with findings in the motor learning literature (e.g., Lam et al., 2009a; Lam et al., 2009b; Liao & Masters, 2001; Poolton et al., 2006), as discussed in the previous chapter. In this regard, the number of rules for the explicit conditions in previous empirical research has outnumbered the single-cue analogy instructions by ratios as high as 12:1 (Liao & Masters, 2001) compared to the 1:1 ratio in the present study. The similarities in the performances of the analogy and explicit conditions lend support to the argument presented in the literature review that the observed advantages of analogy learning could have arisen from the reduced *volume* of instruction and not necessarily the *type* of instruction as previously believed. This reinforces the need to re-examine the differential effects of analogy and explicit information in motor learning contexts.

With regard to joint variability, variability in the elbow joint increased while throwing under the analogy and explicit conditions, regardless of the availability of KR. The reason for the increase may be due to differences in interpretation or understanding between participants even within instructional type. For instance, the 'move your arm like a catapult' instruction generated two primary interpretations, with some participants performing the intended, classic catapult movement, based on the ancient tension device, while others mimicked the movement of the trebuchet, the counterbalanced mediaeval siege weapon. While words may remain unchanged, the use of language varies from person to person (Reed, 1996), so coaches and sport psychologists must ensure that their instruction is relevant to the performers with whom they work. These differences across learners in understanding could also lend further support to alternative SOI, which may be presented in more objective or relevant terms. Because of the within-subjects, semi-counterbalanced design, it is difficult to directly compare participants' elbow joint variability from this study with Bernstein's (1967) predictions, but it is interesting that the introduction of the verbal instruction did lead to an increase in variability under both analogy and explicit conditions, as well as a significant change from the baseline conditions.

Along with instructional type, knowledge of results also had a significant effect on accuracy, as participants achieved better scores when they could see the results of their throws compared to those sets where their vision was occluded. These findings largely support the research of Schorer et al. (2012) with regard to the short-term impact of KR, but the results do conflict with the longer-term learning implications traditionally associated with KR, which is thought to promote hypothesis-testing behaviours and the accumulation of explicit knowledge (Poolton et al., 2005). It may

be that the information gathered through KR is manageable in small chunks, as there is limited explicit knowledge to reinvest into the movement, but the performance benefits dissipate as knowledge regarding the task increases. While the precise nature of the mechanisms governing the effects of KR is not necessarily clear in this instance, the differential effects of KR in motor control versus motor learning situations may represent an important consideration for those working in the field and the laboratory going forward. Interestingly, even though there were significant differences in accuracy with respect to KR and significant kinematic differences with respect to instructional type, KR did not have a statistically significant impact on any of the kinematics-based measures in this study. Participants, however, did demonstrate more variability on average in the elbow joint when KR was available, suggesting that participants may have engaged in hypothesis testing. In this regard, the increased variability could have resulted from technical alterations based on the knowledge of previous throws. While hypothesis testing is ordinarily associated with performance disruption and explicit learning in the previous research of Masters and colleagues, it is possible that it may benefit performers in motor control contexts, as there is limited time for verbal knowledge to accumulate.

As the negative effects of instruction in short-term, motor control situations conflicts with those in motor learning, future research may wish to investigate the persistence of these acute effects. By increasing the number of trials for each piece of instruction, it may be possible to determine at what point verbal instruction begins to benefit performers. While the baseline conditions in this study were always first to ensure that the instructions from the other conditions did not interfere or influence throwing performance, it would also be valuable to know if—and how quickly—

performance might return to baseline levels after receiving verbal instruction. With this in mind, a similar study employing a wholly counterbalanced design across all conditions could prove informative for practitioners and researchers alike.

3.4.1. Conclusion

The results of the present study suggest that coaches, physical educators, and sport psychologists should exercise caution when communicating verbal information intended for immediate use in motor control situations. Given the detrimental effects of both verbal instructional types, researchers, applied practitioners, physical educators, and others working in the field may wish to consider exploring alternative SOI, which may represent information sources that are more relevant to the learners and more readily interpreted. The study also further highlighted methodological issues discussed in the literature review regarding mismatched instructional length, which will require more direct examination.

Chapter 4. Re-examining the effects of verbal instructional type on early stage motor learning

Chapter Aims

This chapter examines the differential effects of analogy and explicit instruction on early stage motor learning and movement in a modified high jump task. For this between-groups study, an explicit light condition was introduced with reduced informational load—in addition to the traditional explicit and analogy conditions—in order to address concerns regarding informational imbalance, as identified in the literature review (section 2.9.2). In addition to measuring the efficiency of the technique to assess learning, the study also sought to investigate the nature of joint variability over learning as a function of instructional condition.

4.1. Introduction

According to the traditional cognitive framework of motor skill acquisition (Anderson, 1982; Fitts & Posner, 1967), the attentional demands and knowledge that underlie motor performance differ with respect to expertise. Although expert performance relies on automatised procedural systems that require minimal conscious awareness, the early stages of skill learning involve the effortful serial processing of explicit rules in working memory systems in order to approximate the successive steps of motor execution. While research indicates that novices may benefit from the self-focused attention engendered by explicit information (e.g., Beilock, Carr et al., 2002), research also suggests that explicit knowledge is associated with skill breakdown under pressure (e.g., Lam et al., 2009b; Masters, 2000; Masters & Maxwell, 2004).

Theorising that explicit, rule-based information might interfere with skilled performance when reinvested into typically autonomous skills, Masters (1992) demonstrated that golf-putting skills acquired implicitly—without reliance on rule-based instruction or working memory systems—were more resilient to induced stressful conditions than those same skills gained through explicit means. Subsequent studies have since shown passively acquired motor skills to be more robust under performance pressure (J. Hardy et al., 2001; L. Hardy et al., 1996; Masters, 1992), physiological fatigue (Masters, Poolton, & Maxwell, 2008; Poolton et al., 2007b), and concurrent cognitive demands (Masters, 1992, 2000) than performance underpinned by declarative knowledge.

However, despite such favourable findings in the laboratory, several factors have limited the application of implicit instructional methods in the field. Much of the difficulty in this regard emanates from the complicated and logistically demanding techniques employed to encourage passive skill learning, such as dual-task learning (e.g., L. Hardy et al., 1996; Masters, 1992; Maxwell et al., 2000), errorless or reduced-feedback learning (e.g., Maxwell et al., 2003; Maxwell et al., 2001) and subliminal learning (e.g., Masters, Maxwell, & Eves, 2001; Masters et al., 2009). Ultimately, these complex implicit learning strategies are difficult for coaches and physical educators to apply in the field and are unrepresentative of real-world sporting environments (Poolton et al., 2006).

To address the issues surrounding implicit learning methods, Masters (2000) introduced the concept of ‘coaching by analogy’, whereby complex movements are conveyed through simple analogical cues. The premise is that such ‘all encompassing biomechanical metaphors’ can be more readily incorporated into current coaching

and instructional paradigms, because they do not require complicated modifications (e.g., dual-task or subliminal learning) to the learning environment, as in earlier implicit learning strategies. Studies have since shown that participants learning tasks through analogical instruction report fewer task-relevant rules (Koedijker et al., 2011; Lam et al., 2009a, 2009b; Liao & Masters, 2001; Poolton et al., 2006), exhibit no deficits in performance or kinematic variables (Lam et al., 2009b), and perform without disruption under stressful (Lam et al., 2009a) or dual-task conditions (Koedijker et al., 2011; Lam et al., 2009b; Liao & Masters, 2001). A methodological issue identified in chapter 2, however, makes it uncertain whether these observed advantages of analogy learning emanate from the *type* of instruction or the reduced *volume* of instructions compared to traditional explicit instructional methods. In this regard, the rules for the explicit conditions in previous empirical research have outnumbered the number of analogy instructions by ratios as high as 12:1 (Liao & Masters, 2001), even though practical coaching guides and current motor learning literature advise against focusing on any more than two or three key points at any one time when teaching new skills (e.g., Mannie, 1998; McQuade, 2003; Schmidt & Wrisberg, 2004). As part of the inspiration behind the concepts of implicit and analogy learning was to reduce the burden on working memory resources imposed by the task instructions, as noted on p. 30, it would be both fair and necessary to also investigate the effects of explicit instructions in their leanest configurations as well. The aforementioned disparity in instructional volume might also explain the propensity for explicit learners to report more task-relevant rules in verbal protocol questionnaires than their analogy group counterparts, as they would have repeatedly read, memorised, and performed up to eleven additional instructional steps. As it

stands, it is impossible to determine whether the performance deficits of the explicit learners—relative to their analogy counterparts—resulted from explicit information itself engendering conscious movement processing or from the volume of that information consuming available attentional resources.

4.1.1. Content under pressure

Although a fairer comparison with explicit learning would represent a positive methodological evolution, additional refinements might further enhance the usefulness of analogy and explicit learning research to those working in applied settings. Just as the impracticalities of implicit learning methods motivated the development of the concept of analogy learning, the artificial manipulations used to simulate pressure or competitive conditions in laboratory research could too benefit from the adoption of a more practical and, perhaps, more representative approach. Part of the initial inspiration for the development of implicit instructional methods was that it might minimise susceptibility to choking (Masters, 1992); however, the choking phenomenon has typically been evaluated using artificial manipulations of pressure and distraction that are often misrepresentative of and disproportionate to the levels experienced in authentic physical activity and performance settings (Gucciardi & Dimmock, 2008; Hill et al., 2010). As discussed in the literature review, this trend has continued in the analogy learning research with prize money (e.g., Lam et al., 2009b), evaluation (e.g., Lam et al., 2009a), audience observation (e.g., Law et al., 2003), and secondary task loads (e.g., Lam et al., 2009b; Orrell et al., 2006) representing the many task-irrelevant methods employed to evaluate the robustness of skills learned under these verbal instruction conditions. Tasks that offer

more authentic pressure manipulations afford richer opportunities for research (Jones & Hardy, 1990), however, as ego-stressor methods only evoke moderate levels of anxiety that are disproportionate to those experienced in real-world sport or physical activity environments (Williams & Elliot, 1999). To further understanding regarding the differential effects of verbal instruction types and to increase the utility of this research for those practising in the field, research designs must reflect the demands and pressures encountered within authentic contexts (cf. Pijpers et al., 2005; Pijpers et al., 2003).

4.1.2. The current study

The present study sought to address concerns regarding informational imbalance and representative pressure by introducing an explicit condition with reduced instructional volume and by implementing a task-appropriate pressure manipulation in a modified high jump task. In taking these steps, the primary aim of the study was to investigate the differential effects of analogy and explicit instruction on movement learning and performance. The choice of a high jump task offered both a technique that was well suited to analogy (the scissor style) and a controllable performance-related pressure (bar height) inspired by the authentic pressure manipulation of climbing height previously used by Pijpers and colleagues (2005; 2003). In competitive contexts, the rising height of the bar is associated with increasing levels of pressure and anxiety, especially as the bar begins nearing heights perceived to be at the limits of one's capabilities (for accounts, see Kangaroo Track Club, 2010; Lee, 2010). Although all aspects of the jump should remain consistent from one attempt to the next (Gillespie, 2007), anecdotal evidence indicates that the

anxiety that accompanies higher bar heights can affect the execution of movements (e.g., Keogh, 2015), resulting in failed attempts, even though clearances at previous heights suggest the physical and technical capabilities for success. In using this task, it was of particular interest to learn if verbal instructional type differentially affected either the accumulation of declarative knowledge or technical performance under the task-relevant pressure conditions.

Just how instructional type affects coordination *during* the jumping movement itself—and not simply the result of the jump—is also of particular interest to this study. While recent research has explored the impact of pressure or anxiety on movement (e.g., Collins, Jones, Fairweather, Doolan, & Priestley, 2001; Pijpers et al., 2005; Pijpers et al., 2003), only a single study, to date, has compared the differential impact of explicit and analogy instruction on movement mechanics. In that one study, however, Lam et al. (2009b) did not find any kinematic differences between analogy and explicit learners, so the possible effects of these two instructional types on movement coordination remain unclear, as noted in chapter 2 (p. 37). To gain greater insight into movement, a number of sport science researchers have advocated a transition from descriptive biomechanical analyses to more analytical approaches for conceptualising and appraising movement mechanics (e.g., Elliot, 1999; Glazier et al., 2003; Nigg, 1993). In recent years, researchers have increasingly investigated changes in movement coordination using methods inspired by concepts rooted in dynamical systems theory (Hodges et al., 2005; Pijpers et al., 2005; Pijpers et al., 2003), rather than the traditional cognitive perspectives, because of dynamical systems theory's interdisciplinary approach to coordination and motor control (Glazier, Davids, and Bartlett, 2002, 2003).

Although the current study was not primarily concerned with dynamical systems theory per se, the theory offers a framework for exploring, quantifying, and understanding movement and coordination, by examining the control and movement of joints, largely inspired by Bernstein's (1967) proposed universal motor learning solution. According to Bernstein (1967), learners constrain movement early on by rigidly fixing joint angles in order to reduce the number of degrees of freedom requiring active control, before gradually releasing them over practice and transitioning to smoother, more economical movement. This process of freeing degrees of freedom should be characterised by increasing variability within and between joints (Vereijken et al., 1992). A secondary aim of the study, therefore, was to examine differences in joint variability to investigate how instructional type affects the nature of motor learning. As Bernstein's motor learning solution is intended as a universal theory, it was of particular interest to see if variability differed in any way with respect to instructional type.

4.2. Method

4.2.1. Participants

Twenty-one healthy male volunteers (mean age = 23.7 years, $SD = 4.3$) were randomly assigned to one of three experimental conditions: the analogy condition ($n = 7$), the explicit light condition ($n = 7$), or the traditional explicit condition ($n = 7$). Participants were considered novices in high jump if they had not received any formal coaching instruction in the event (Poolton et al., 2006, 2007b). Two participants from the traditional explicit condition were excluded from the study following data collection for failing to follow the task instructions; consequently, two

new participants were recruited using purposive sampling techniques to ensure equal-sized groups. Following previous precedent (e.g., Lam et al., 2009a; Poolton et al., 2006), a control group was not included as research suggests that these uninstructed groups perform identically to traditional explicit conditions (Lam et al., 2009a) by learning explicitly, reporting high levels of rule-based knowledge, and exhibiting disrupted performance under anxious or dual-task conditions (e.g., Liao & Masters, 2001; Masters, 1992). All participants provided informed consent prior to commencing their involvement in the research. Ethical approval for the study was granted by the University of Edinburgh School of Education ethics committee.

4.2.2. Apparatus and task

The setting for the study was a purpose-built sport science laboratory with rubber flooring similar to a running track surface. A rectangular ‘take-off’ area, as illustrated in figure 4.1, was clearly marked on the floor to limit the length of the run-up and to ensure that participants approached the bar at an angle of 30° in line with recommended high jumping technique (Morgan, 2002). Following advised practice for novice jumpers, the approach run was restricted to two steps, because it allows learners to develop a sense for the rhythm, technique, and body positioning necessary for the high jump (American Sport Education Program, 2008; Otte, 1999) without having to worry about the speed and strength required to perform the fast, curved full-length approach.

Due to constraints arising from the layout and design of the laboratory, it was possible to accommodate run-ups from only a single side. As all participants were

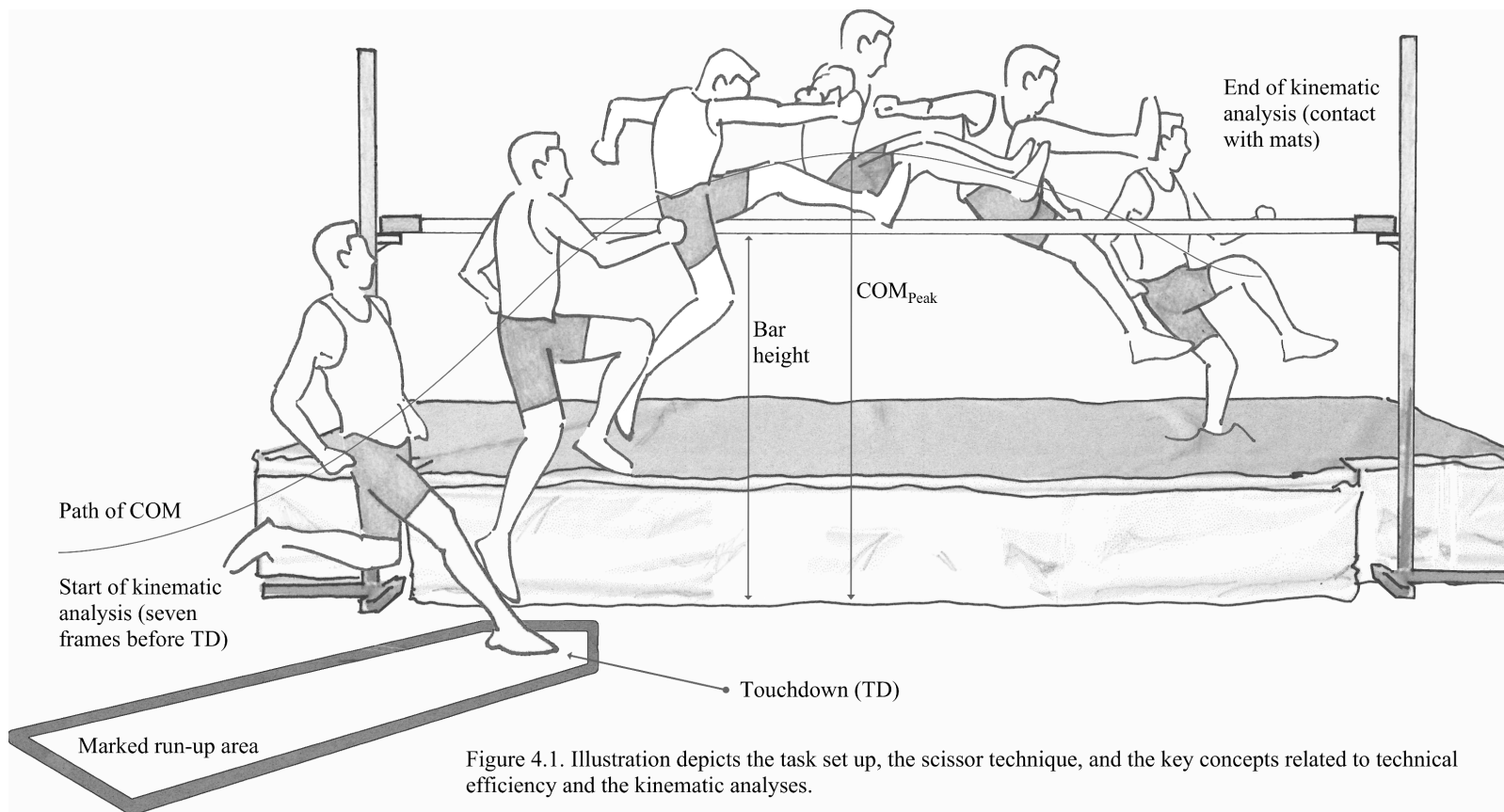


Figure 4.1. Illustration depicts the task set up, the scissor technique, and the key concepts related to technical efficiency and the kinematic analyses.

novices and laboratory research has demonstrated similar leg kinematics and kinetics between both dominant and non-dominant legs in jumping tasks (van der Harst, Gokeler, & Hof, 2007), it was not expected that the use of either leg would affect learning or performance in the scissor technique. Because it is most common for individuals to approach from the right side to use their left foot in high jumping tasks (Peters, 1988), however, the left side was chosen to limit skill transfer from related tasks or activities.

Three Canon MD101 video cameras recording at 50 fields per second filmed the jumping trials for the biomechanical analyses. As depicted in figure 4.2 (p. 77), the cameras were positioned approximately 90° to each other, but adjusted accordingly to ensure that all cameras had a view of the run-up area and the high jump bar with minimal obstruction from task apparatus (e.g., high jump standards and mats). The image space was calibrated before and after each session using a custom-built metal frame measuring 1.90 m × 1.90 m × 2.89 m (Coleman & Rankin, 2005). To obtain the kinematic data, the positions of eighteen body landmarks including joint centres and limb extremities were manually digitised, transformed into three-dimensional coordinates using the direct linear transformation method (Abdel-Aziz & Karara, 1971), and smoothed using the APAS three-dimensional motion analysis system (Ariel Performance Analysis System; Ariel Dynamics, Inc.; San Diego, CA, USA).

4.2.3. Design

The experiment featured a mixed design comprising a two-day learning phase and a single-day testing phase. Because high jump athletes do not make many full-

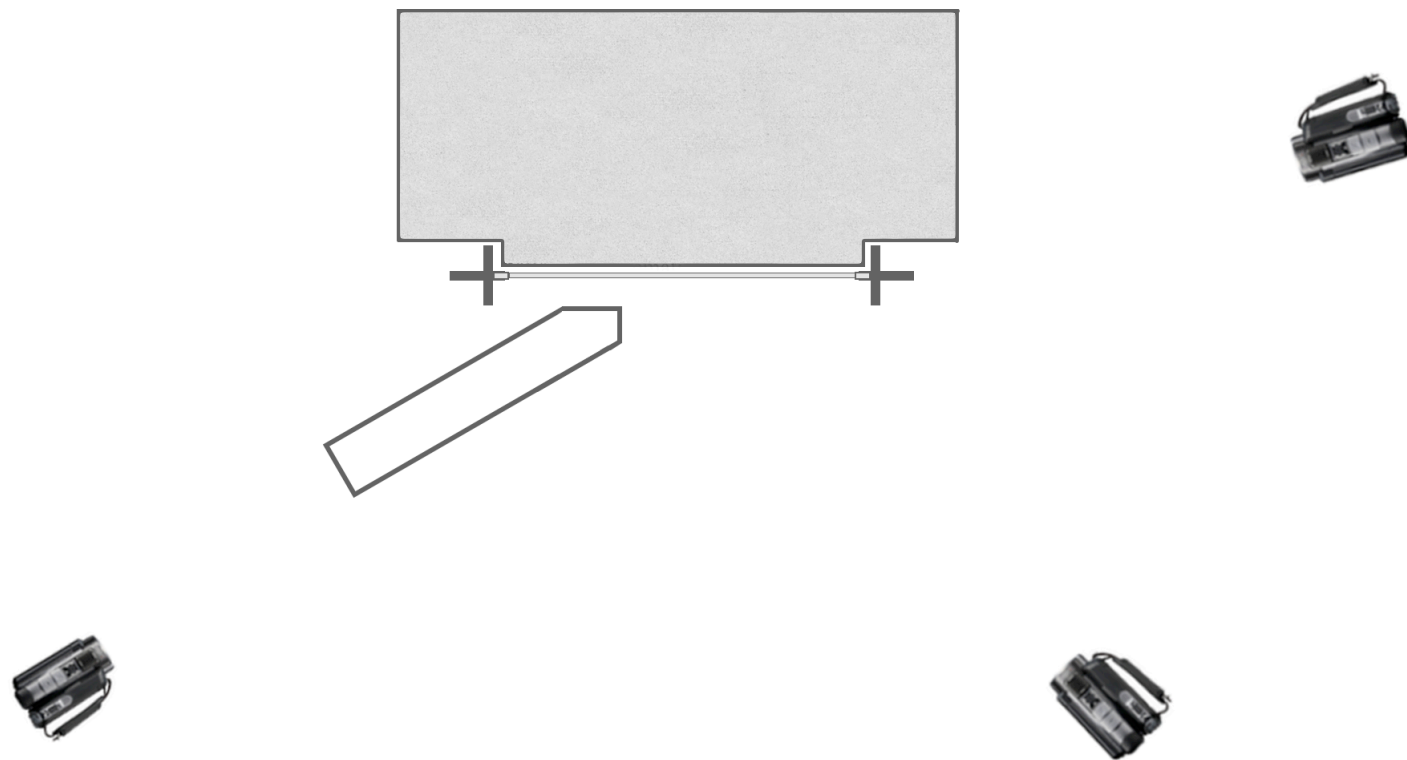


Figure 4.2. Illustration of the task set up from above to show placement of the three video cameras for the kinematic analyses relative to the high jump mats, bar, and run up area.

Figure Legend



Camera



Run Up Area



Landing Mats and Standard

effort jumps in a single session (Dapena, McDonald, & Cappaert, 1990)—typically between 10 and 20 jumps in three sessions weekly (Keogh, 2015)—learning trials were reduced compared to previous research (e.g., Lam et al., 2009a, 2009b; Liao & Masters, 2001; Poolton et al., 2007b) to make the design more representative of real-world practice and to limit the possibility of fatigue impacting performance. During the learning phase, participants performed 2 identical blocks of 10 jumps for each day of learning. The testing phase, in contrast, was divided into two distinct parts: a retention test and task-relevant pressure test. During the retention test, which was used to assess learning and provide a baseline for the testing phase, participants again performed 10 jumps. For the task-relevant pressure test, however, participants continued jumping until they recorded three successive failures in accordance with the competition rules of the high jump. Between all days of the study, participants received 47 hours rest to allow for sufficient recovery (i.e., they attended the lab at the same time every other day).

4.2.4. Procedure

Participants individually learned and performed the scissor-style high jump technique using the instructions for their respective conditions by jumping over a foam-covered, low-height elastic band held in position by two uprights. In order to simulate competitive conditions, a 4-m high jump bar replaced the elastic band during the task-relevant pressure test and was raised 5 cm following each successful clearance. The height of the elastic band, which remained unchanged for the learning phase and retention test to prevent hypothesis testing (Maxwell et al., 1999), was systematically calculated using a modified model for predicting Fosbury Flop

performance (Laffaye, 2011). This calculation, which was based on the physical characteristics and vertical-jumping reach height of each participant, also served as the starting height for the bar during the task-relevant pressure test. For reasons concerning both safety and technique, participants were informed that they must always land upright (i.e., on one or both feet) and only use the clearly marked run-up area for their approach and jump. Participants—who all warmed up with dynamic stretching exercises upon arrival (Ebben & Petushek, 2010)—were afforded 40-s rest between all jumps during both the learning and testing phases.

The instructions for the experimental conditions were compiled from a variety of sources (American Sport Education Program, 2008; Morgan, 2002; Shepherd, 2009) and tailored as appropriate to suit the nature of the experimental conditions (see table 4.1 on p. 80 for list of instructions for each group). Participants were asked to read through the instructions for their respective groups before commencing each block of jumps in the learning phase. For the testing phase, participants were not reminded at any point of their instructions, but were asked to maintain effort and maximise jumping performance, following the example of previous research (Lam et al., 2009b). Throughout the study, the technique was called the ‘Penn State style high jump technique’ to mitigate the possibility of any possible prior knowledge or awareness of the scissors style affecting participant performance. For the task-relevant pressure test, trials were deemed successful only if the participants both jumped over the bar without dislodging it (i.e., the bar stayed on the standards) and landed upright on the mats.

Table 4.1. *Instructions for the Experimental Conditions*

Condition	Instructions
Analogy	<p>Keep your upper body tall like a pencil through takeoff</p> <p>Alternate your legs like scissors to clear the bungee cord</p>
Explicit Light	<p>Keep upper body tall through takeoff</p> <p>Lift left leg up over the cord and bring down</p> <p>Repeat action with right leg</p>
Traditional Explicit	<p>Stand with your feet together at 30° to the crash mats</p> <p>Take two steps toward the mats, leading with your left leg</p> <p>As you complete the second step, firmly plant your right foot on the floor 45-60 cm from the mats</p> <p>Jump up using your right leg, fully extending off of your toe (so leg is straight), while driving your left knee</p> <p>Lift your left leg up and over the cord and bring down</p> <p>Repeat this action with right leg</p> <p>Land upright, standing on your left leg</p> <p>Maintain a vertical position with upper body throughout</p>

4.2.5. Dependent variables

4.2.5.1. Psychological measures

Subjective anxiety was measured at the end of the learning and testing phases using the ‘anxiety thermometer’—a self-report measure used in recent anxiety-performance research (Lam et al., 2009a; Pijpers et al., 2005; Pijpers et al., 2003) with moderate to high correlation ($r = .64$ to $.77$) with the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970)—which asked participants to rate their current level of anxiety by placing a cross on a 10-cm continuous scale, ranging from 0 (left end; not anxious at all) to 10 (right end; extremely anxious). The physical distance in centimetres between the left edge of the scale and participants’ crosses was used as the measure of self-reported anxiety.

Self-reported mental effort was assessed using the Rating Scale for Mental Effort (RSME; Zijlstra, 1993), which has been employed previously to measure effort in sport (e.g., Cooke, Kavussanu, McIntyre, & Ring, 2010; Wilson, Smith, & Holmes, 2007), and has demonstrated acceptable reliability in both laboratory and work settings ($r = .88$ and $.78$ respectively; Zijlstra, 1993). At the conclusion of both the learning and testing phases, participants were asked to rate the amount of effort invested during performance on a vertical axis scale ranging from 0 to 150. Nine category anchors illustrated points throughout the continuum, including 3 (no mental effort at all) and 114 (extreme mental effort) at the extremes.

4.2.5.2. Psychophysiological measures

Harrison et al. (2001) and McKay et al. (1997) argued that sports competition

incites cardiovascular responses that extend beyond the typical physiological effects of the task. If the bar height manipulation evokes physiological effects representative of real-world competitive conditions, it was expected that the average heart rate readings would increase in the task-relevant pressure test relative to all other sets. With this in mind, heart rate was measured using Polar Electro Sports Testers (Polar Electro, Finland), in order to evaluate the effectiveness of the task-relevant pressure manipulation and levels of physiological arousal during the task (e.g., L. Hardy & Parfitt, 1991). Readings were collected in 5-s intervals using heart rate transmitters and data receivers that were fitted to each participant's chest and wrist.

4.2.5.3. Amount of verbal knowledge

Based on the verbal protocols of Lam et al. (2009b), immediately following the task-relevant pressure test, participants were asked to reflect upon their performances and describe in as much detail as possible 'any methods, rules, or techniques that they remembered using while performing the high-jumping task during both the learning and test phases'. Two independent raters examined all reports—following the methods and criteria set forth by Lam et al. (2009b) and Poolton et al. (2007a)—to count the number of rules reported by each participant. Only statements referring directly to technical or mechanical aspects of high-jumping technique were counted; any statements unrelated to task performance were excluded from the tally. In this instance, the verbal protocol questionnaire not only served as a measure of the accumulation of explicit knowledge, but also as a control measure to ensure that participants were focused only on the instructions for their respective conditions. In this regard, the verbal protocols helped to reveal that two of the participants had

intentionally disregarded the task instructions and attempted to employ knowledge from other skills (i.e., basketball), leading to their exclusion from the study.

4.2.5.4. Technical efficiency

Unlike a typical high jump competition, the highest successful clearance is not necessarily meaningful in the present study due to the shortened approach run, which could overemphasise physical differences between participants. For this reason, based on the methods of Hay and Reid (1982) and Dapena (1992), a standardised measure of technical efficiency was calculated to assess learning for each participant by dividing the clearance height (i.e., height of the bar or elastic band) by the peak height of the centre of mass (COM; see figure 4.1 on p. 75 for illustration). Higher ratings represent more efficient clearances, while lower ratings indicate less efficient clearances in which technique inhibited maximisation of flight height. Technical efficiency was calculated for all jumps of the learning phase and for the highest clearance for each participant during the task-relevant pressure test. It was expected that traditional explicit participants would demonstrate less technical efficiency than their analogy and explicit light counterparts, because of the additional instructional load compared to the other two groups.

4.2.5.5. Joint variability

To explore the effects of instructional type on joint variability, the standard deviations around the mean (Glazier, 2011; Vereijken et al., 1992) were calculated for four specific joints: left knee, left hip, right knee, and right hip. The knees and hips not only represent important considerations for optimising technique (see

figure 4.1 for depiction of the scissor style) according to the coaching literature (e.g., American Sport Education Program, 2008; P. Reid, 2010), but also for maximising the height of the COM according to biomechanical analyses (e.g., Dapena, 2000; Dapena et al., 1990; Greig & Yeadon, 2000). In this regard, biomechanical research has identified the angle of the jumping leg at touchdown (the moment the jumping leg first contacts the floor; Dapena, 2000; Dapena et al., 1990), the drive action of the non-jumping leg at takeoff (the moment the jumping leg leaves the floor; Greig & Yeadon, 2000), and the positioning of the hips throughout the takeoff phase (i.e., from touchdown to takeoff; Dapena, 2000; Dapena et al., 1990) as important factors in high jumping performance. Although previous research has investigated joint variability by comparing standard deviation within and across joints without any transformation (e.g., Vereijken et al., 1992), the standard deviation data in this instance were converted into CV prior to analysis to eliminate the mean differences between individual participants (James, 2004; Lam et al., 2009b).

4.2.6. Analyses

As shown in table 4.2 (p. 85), kinematic data were collected and analysed for the first, fourth, and tenth jumps in each block for both phases, based on precedents from related research (e.g., Hodges et al., 2005; Vereijken et al., 1992; Zentgraf & Munzert, 2009), except in the case of the task-relevant pressure test, in which the highest clearance by each participant became the final measurement trial. Across all participants, the best clearances on average typically occurred on or near the ninth trial ($M = 9.38$, $SD = 1.20$). In order to cover the touchdown, takeoff, and flight phases of the jump, the starting and ending points for the analysis were defined as

seven frames (0.14 sec) before the moment of touchdown and the precise moment that participants landed on the crash mats following the jump, respectively (see figure 4.1 for illustration). The mean duration for the kinematic analyses across all trials was 0.79 sec ($SD = 0.03$).

Table 4.2. *Practice Schedule with Indication of Measurement Trials*

Block	Cumulative number of practice trials	Measurement trials	Cumulative number of measurement trials
1	10	1, 4, & 10	3
2	20	11, 14, & 20	6
3	30	21, 24, & 30	9
4	40	31, 34, & 40	12
5	50	41, 44, & 50	15
6	60	51, 54, & top clearance	18

During analysis, any violations of the assumption of sphericity were corrected using Greenhouse-Geisser procedures based upon the advice of Field (2005) and the precedent established by preceding research (e.g., Hodges et al., 2005; Lam et al., 2009b). Post hoc analyses employed Bonferroni's method to control for type I error (Field, 2005), unless otherwise noted. All results reported as significant at the .05 level.

4.2.7. *Digitising accuracy and precision*

Digitising accuracy was evaluated by digitising a moving 70 mm rigid segment using the same method as participant analyses (Salter et al., 2007; Wormgoor et al.,

2010). The mean reconstructed length of the segment was $72 \text{ mm} \pm 3.8$, resulting in a mean error of 2 mm (2.9%), in line with results from the aforementioned studies. To assess digitising precision (Challis, 1997; Coleman & Rankin, 2005), a single jumping trial was digitised six separate times and, from these data, typical errors (Hopkins, 2000) were then calculated. Repeated digitisation yielded typical errors for the COM of $\pm 4 \text{ mm}$, $\pm 2 \text{ mm}$, $\pm 3 \text{ mm}$ in the x , y , and z axes, respectively.

4.3. Results

4.3.1. Technical Efficiency.

4.3.1.1. Learning phase.

To investigate the efficiency of the scissor technique with respect to condition, a 3×4 (Condition \times Block) mixed design ANOVA with repeated measures on the latter factor was run on the technical efficiency data for the learning phase. Although participants from the analogy group demonstrated greater efficiency on average ($M = .60$, $SD = .033$, $SE = .012$) than both their explicit light ($M = .591$, $SD = .041$, $SE = .015$) and traditional explicit counterparts ($M = .572$, $SD = .032$, $SE = .012$); these differences were not statistically significant overall, $F(2, 18) = .959$, $p = .402$, $\eta_p^2 = .10$. There was, however, a significant within-subjects effect for block, $F(3, 54) = 6.516$, $p = .001$, $\eta_p^2 = .27$, as efficiency increased across conditions as the learning phase progressed. These data pertaining to technical efficiency during the learning phase are presented in figure 4.3 (p. 88).

4.3.1.2. Testing phase.

A one-way ANOVA was used to evaluate technical efficiency for the highest

clearance of each participant during the task-relevant pressure test. Although the results approached significance, the differences with respect to instructional type were non-significant overall, $F(2, 18) = 3.137, p = .07, \omega = .47$. As in the learning phase, participants from the analogy group again demonstrated greater efficiency ($M = .80, SD = .013, SE = .005$) than those from the explicit light ($M = .774, SD = .035, SE = .013$) and traditional explicit conditions ($M = .755, SD = .0377, SE = .014$). The mean technical efficiency as a function of condition during the testing phase is shown in figure 4.4 (p. 88).

4.3.2. *Verbal rules*

The accumulation of task-relevant explicit rules for each participant was assessed by two independent raters and then averaged into a single score. Intra-class correlation coefficients, which were used to evaluate inter-marker reliability (Lam et al., 2009b; Poolton et al., 2007a), indicated significant correlations between both markers ($ICC = .91, p < .001$). A one-way ANOVA of the data revealed that the analogy condition ($M = 5.71, SD = 3.68$) reported fewer rules on average than the explicit light ($M = 6.29, SD = 1.87$) and traditional explicit conditions ($M = 7.86, SD = 2.14$), but the differences between the three conditions were not significant, $F(2, 20) = 1.196, p = .325, \omega = .17$. There was, however, a statistically significant negative relationship between the number of reported explicit rules and technical efficiency, $r = -.53, p < .05$.

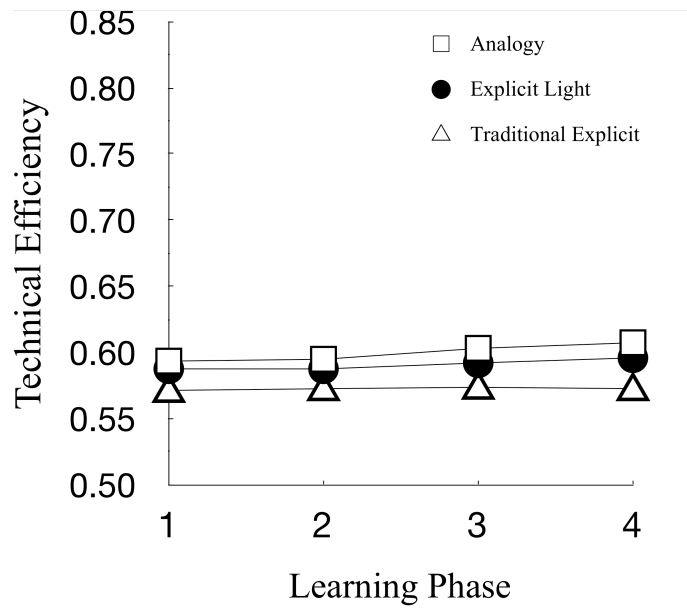


Figure 4.3. Mean technical efficiency as a function of condition during the learning phase.

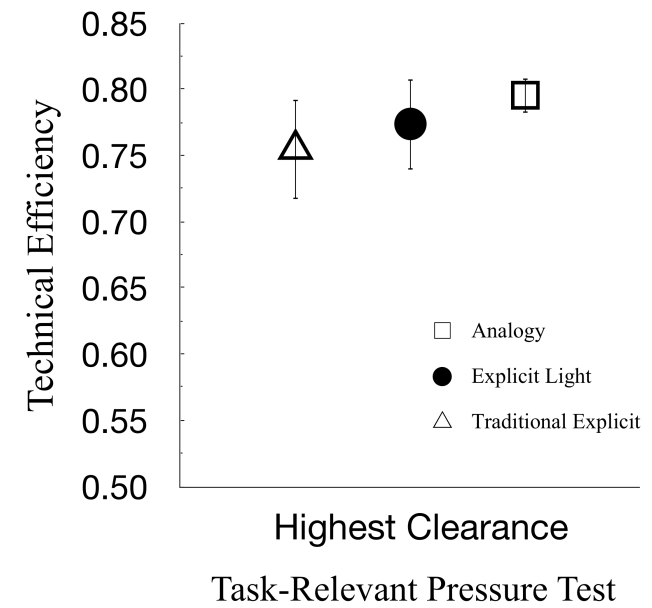


Figure 4.4. Mean technical efficiency for highest clearance in the task-relevant pressure test as a function of condition. Error bars show standard deviation.

4.3.3. Joint variability

4.3.3.1. Learning phase.

A $3 \times 4 \times 4$ (Condition \times Joint Angle \times Block) ANOVA with repeated measures on the latter factor was conducted for joint variability. Prior to analysis, the CV data were inverse square root transformed to normalise the distribution and then reflected to restore the direction of the relationships between variables. Analysis indicated that there was a statistically significant main effect of condition, $F(2, 18) = 16.688$, $p < .001$, $\eta_p^2 = .65$, with post hoc tests revealing that the analogy group demonstrated significantly less variability across all joints ($M = 1.29$) than either the explicit light, $M = 1.84$, $p < .001$, or traditional explicit conditions, $M = 1.64$, $p < .01$. There was also a significant finding for joint angle, $F(1.991, 35.837) = 51.194$, $p < .001$, $\eta_p^2 = .74$, indicating that variability was not consistent between joints. A closer inspection of the data showed that variability was highest for the left hip ($M = 2.02$, $SE = .02$) and lowest for the right knee ($M = 1.17$, $SE = .08$). Analysis revealed a significant effect for block as well, $F(1.952, 35.133) = 5.376$, $p < .01$, $\eta_p^2 = .23$, with variability across all joints decreasing as the learning phase progressed (see figure 4.5 on p. 90), contrary to expectations from a dynamical systems theory perspective.

A significant interaction was detected between condition and joint angle, $F(3.982, 35.837) = 9.897$, $p < .001$, $\eta_p^2 = .52$, meaning that the variability between joints differed with respect to condition. Simple effects analysis indicated that there were significant differences between conditions for left knee, $F(2, 18) = 6.404$, $p < .001$, right knee, $F(2, 18) = 15.693$, $p < .001$, left hip, $F(2, 18) = 2.480$, $p < .05$, and right hip, $F(2, 18) = 2.682$, $p < .05$. For all of these joint angles, the analogy condition demonstrated less variability than either of the other two conditions, while

the explicit light condition exhibited the greatest variability in all instances, as shown in figure 4.6 (p. 92).

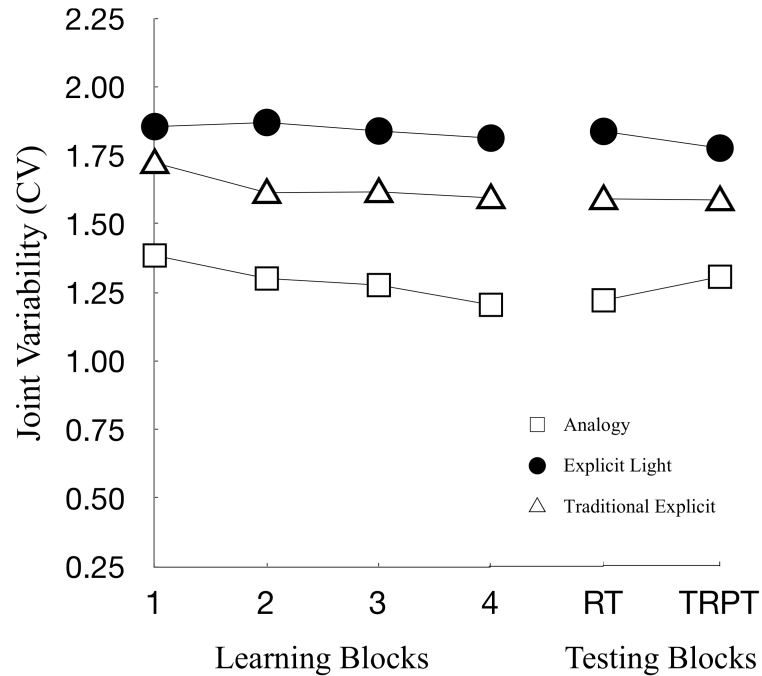


Figure 4.5. Transformed CV values for joint variability averaged across joint angles for each condition during the learning and testing phases (retention test and task-relevant pressure test)

4.3.3.2. Testing phase.

A $3 \times 4 \times 2$ (Condition \times Joint Angle \times Block) ANOVA with repeated measures on the latter factor was conducted on joint variability data for the testing phase. Data were once again inverse square root transformed and reflected prior to analysis. Despite these steps, however, equal variances still could not be assumed for the right hip angle during the task relevant pressure test ($p = .03$). Howell (2009) noted, however, that ANOVA is robust against small violations of homoscedasticity such as this, especially when sample sizes are equal. Following the advice of Field

(2005), the Games–Howell procedure was used in place of the Bonferroni method as it offers the best performance when there is any doubt regarding the equality of variances.

A significant main effect was found for condition, $F(2, 18) = 11.770, p = .001, \eta_p^2 = .57$, with the analogy group again demonstrating less variability on average ($M = 1.26$) than either the explicit light, $M = 1.81, p < .01$, or traditional explicit conditions, $M = 1.59$, although the differences were only significant compared to the former in this instance (see figure 4.5 on p. 90). There was also a significant effect for joint angle, $F(1.921, 34.572) = 55.145, p < .001, \eta_p^2 = .75$. Once more, variability was highest for the left hip ($M = 2.02, SE = .03$) and lowest for the right knee ($M = 1.09, SE = .10$), echoing the findings in the learning phase.

Unlike the learning phase, there was no significant effect for block, but there was a significant condition \times joint angle interaction, $F(3.841, 34.572) = 6.843, p < .001, \eta_p^2 = .43$. Simple effects analysis revealed significant differences between the conditions for left knee, $F(2, 18) = 5.700, p = .001$, right knee, $F(2, 18) = 13.270, p < .001$, and right hip, $F(2, 18) = 3.592, p < .05$. As shown in figure 4.6 (p. 92), for each of the joints, the explicit light condition demonstrated the greatest joint variability on average, followed by the traditional explicit and analogy conditions, respectively.

Analysis of variance revealed another significant interaction between joint angle and block, $F(1.932, 34.769) = 22.041, p < .05, \eta_p^2 = .55$, indicating that the nature of the variability between joints changed from the retention test to the task-relevant pressure test. Unlike the learning phase, which saw variability generally decrease with learning for each joint, there was no such clear pattern for the testing phase. Finally, there was also a significant three-way interaction between condition,

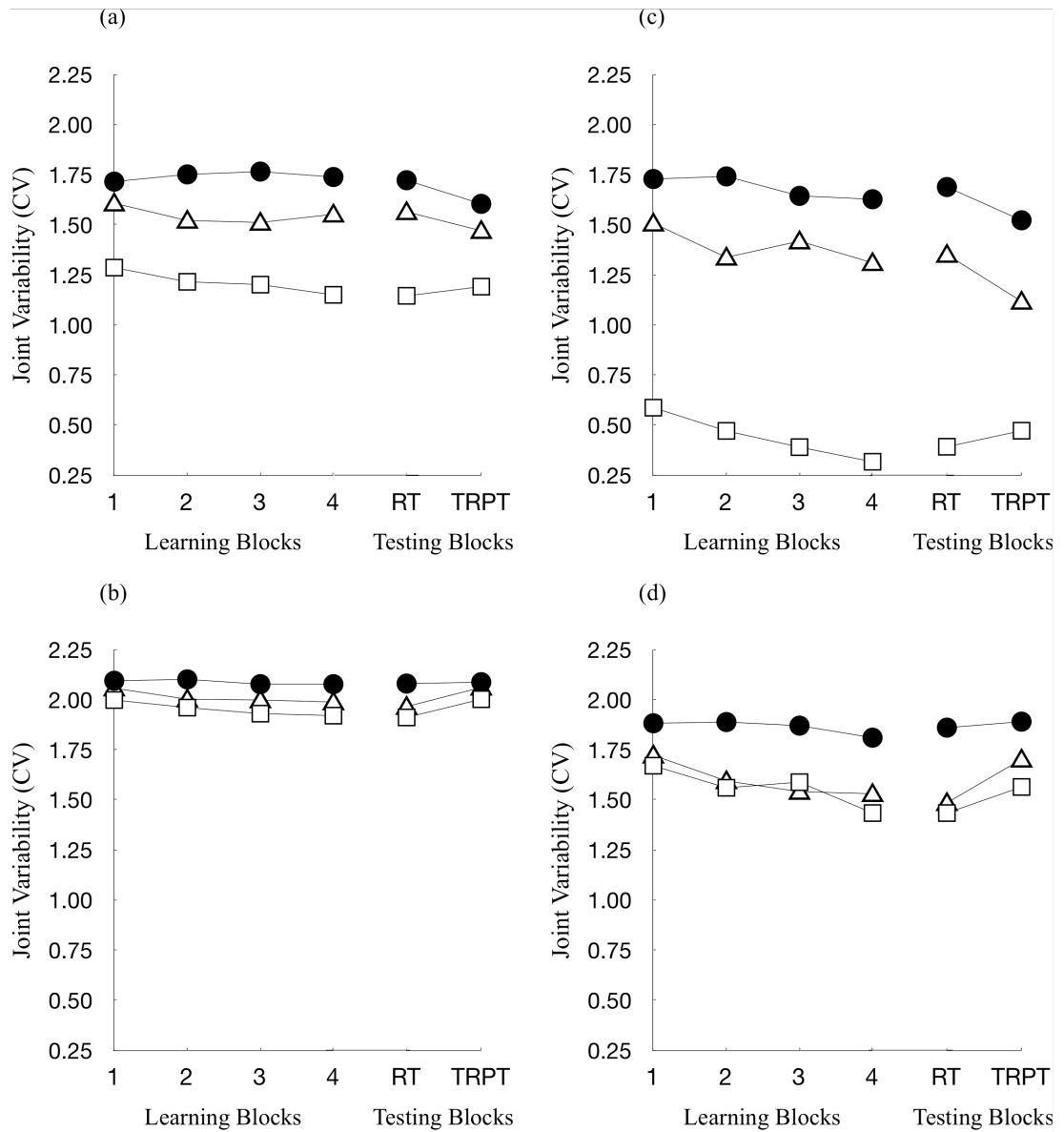


Figure 4.6. Transformed CV values as a function of condition over the learning phase and testing phase (retention test and task-relevant pressure test). (a) Left Knee (b) Left Hip (c) Right Knee (d) Right Hip. □ – Analogy, ● – Explicit Light, △ – Traditional Explicit

joint angle, and block, $F(3.863, 34.769) = 5.144, p < .005, \eta_p^2 = .36$. To follow-up this significant interaction, three separate two-way (Joint Angle \times Block) repeated-measures ANOVAs were conducted (Mullen & Hardy, 2000). To guard against inflation of type I error due to these multiple comparisons, the critical p value was changed to .0125 using a Bonferroni adjustment. Analyses revealed that there was a significant interaction effect between joint angle and block for the explicit light, $F(2.024, 12.145) = .8.991, p < .005, \eta_p^2 = .60$, and traditional explicit conditions, $F(3, 18) = .17.341, p < .001, \eta_p^2 = .74$, but the interaction was non-significant for the analogy learners, $F(3, 18) = .894, p < .05, \eta_p^2 = .13$. An inspection of the data showed that variability for every joint angle increased from the retention test to the task-relevant pressure test for those in the analogy condition, whereas the variability increased only for the left and right hip joints in the case of the explicit light and traditional explicit conditions.

4.3.4. Effectiveness of Pressure Manipulation

To investigate the effectiveness of the pressure manipulation, a 3×2 (Group \times Block) MANOVA with repeated measures on the latter factors was performed on anxiety thermometer, RSME, and average heart rate data for the last block of the learning phase and the task-relevant pressure test during the test phase. Analysis did not reveal any between-subjects effects, $F(6, 34) = 1.057, p = .407$; however, there was a significant within-subjects effect for block, $F(3, 16) = 44.88, p < .001$. Pairwise comparisons showed that anxiety thermometer scores, RSME scores, and average heart rate all increased for the task-relevant pressure test, suggesting that the pressure manipulation was successful (see table 4.3 on p. 94).

Table 4.3. *Comparison of Anxiety Thermometer, RSME, and Average Heart Rate*

	Last Learning Block		Task-Relevant Pressure Test	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Anxiety Thermometer *	1.09	0.30	3.23	0.41
Rating Scale for Mental Effort *	58.14	4.87	79.57	3.84
Average Heart Rate * (beats per min)	97.4	2.7	107.3	3.0

* Difference between blocks significant at $p < .001$ level

4.4. Discussion

In this chapter, previous work in this area was refined by matching the volume of information distributed to both the analogy and explicit light conditions, while still including a traditional explicit condition to facilitate comparison with earlier studies. With the amount of instruction controlled, the primary aim of the study was to then explore the effects of these differential instructional sets on movement learning and performance.

It has been thought that analogy learning promotes implicit skill acquisition that is more robust to performance pressures and less demanding on attentional resources than explicitly acquired skills. To investigate this, the current study measured the efficiency of technique and the accumulation of verbal knowledge as a function of condition. With regard to technical efficiency, the three conditions performed similarly throughout the learning phase, exhibiting comparable levels of increasing efficiency (see figure 4.3). During the task-relevant pressure test,

differences in technical efficiency between the conditions for highest clearance became more pronounced, although these differences did not reach statistical significance, as shown in figure 4.4 (p. 88). This non-significant finding corresponds with the results of Lam et al. (2009b), who did not find any significant differences in shooting performance between analogy and explicit learners in a basketball-shooting task. It cannot be ruled out, however, that differences between the conditions in this study might have been diminished due to contextual guidance, as some of the instructions for the traditional explicit condition, for instance, did not necessarily require explicit explanation because of the well-controlled experimental set up. At the same time, it is also important to recognise that the differences between the traditional explicit and analogy conditions would have been statistically significant had this study followed the typical design of the preceding research and not included the explicit light condition.

From an applied perspective, there is practical significance in the less efficient—and more variable—technical performance of the traditional explicit condition compared to the analogy and explicit light conditions with their lightened informational loads. For coaches, physical educators, and practitioners in the field, it is also interesting to note that only one traditional explicit participant managed a third-attempt clearance—three fewer than each of the other two conditions—even though every participant would have had *at least* one opportunity to do so (see table 4.4). In the context of high jump, every additional clearance is meaningful and the practical value of pressure-laden third-attempt clearances is difficult to understate. The similarity between the analogy and explicit light conditions in this regard has implications regarding the impact of instructional volume on performance, although

the analogy group still performed better on average. In fact, in applied settings, the higher, more consistent, and more efficient clearances of the analogy learners—compared to their explicitly instructed counterparts—would be difficult for coaches or physical educators to ignore.

Table 4.4. *Mean Cumulative Totals for Each Condition During Task-Relevant Pressure Test*

	Successful Clearances		Successful Third Attempt Clearances		Failures*	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Analogy	7.86	0.90	0.57	0.53	2.00	1.00
Explicit Light	7.43	1.27	0.57	0.53	2.14	1.07
Traditional Explicit	7.86	1.07	0.14	0.38	0.86	1.21

* Excludes final three failures for each participant that ended the task-relevant pressure test

With regard to verbal knowledge, the very nature of explicit instruction is thought to promote its accumulation, (Lam et al., 2009b; Liao & Masters, 2001; Masters & Maxwell, 2004; Poolton et al., 2006), however, the explicit light condition reported fewer task-relevant rules on average than the traditional explicit group, suggesting that instructional type alone cannot account for the accumulation of task-relevant knowledge. That said, the analogy condition still demonstrated greater technical efficiency and reported fewer task-relevant rules than the explicit light condition, suggesting that the reduction of instructional volume fails to fully explain the differences observed between the groups. It may be that the accumulation of

Table 4.5. Comparison of Mean Values for Highest Clearance During Task-Relevant Pressure Test as a Function of Condition

	Standing Height (m)		Highest Clearance (m)		Technical Efficiency		COM _{TD} (m)		COM _{TO} (m)		COM _{Peak} (m)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Analogy	1.81	0.08	1.25	0.08	0.80	0.01	0.93	0.05	1.30	0.05	1.57	0.05
Explicit Light	1.81	0.09	1.21	0.09	0.77	0.03	0.93	0.04	1.29	0.07	1.57	0.05
Traditional Explicit	1.83	0.06	1.22	0.06	0.75	0.04	0.97	0.03	1.31	0.05	1.61	0.07

COM_{TD} refers to the height of the COM at touchdown when the jumping leg first contacts the floor to initiate the jump.

COM_{TO} represents the height of the COM at takeoff, the moment that the jumping leg loses contact with the floor.

COM_{Peak} is the COM at the maximum height of the jump.

verbal knowledge is moderated not by the volume of instruction, which was matched in word count between the analogy and explicit light conditions (see table 4.1), but by the number of rules or movement components within those instructions, as the explicit light instructions contained one additional rule—with one of those rules referencing two movement components (i.e., lift leg over the cord and bring back down). Without further investigation, it is difficult to determine whether the accumulation of task-relevant knowledge resulted from disparate properties of the instructions themselves or a discrepancy in the number of rules within these instructions. At the very least, however, the results for both technical efficiency and reported verbal rules demonstrate that more information is neither necessary nor particularly helpful for learners.

A secondary aim of the study was to investigate differences in movement coordination with respect to instructional type. Kinematically, it was hoped that the adoption of analysis techniques inspired by research in dynamical systems theory would assist in identifying and contextualising any unique biomechanical characteristics engendered by the experimental conditions. Based on previous biomechanical analyses, the technical demands of the scissor jump, and Bernstein's (1967) hypothesised motor control strategy of freezing and freeing degrees of freedom, joint variability around the mean in the knees and hips was examined for both phases of the study. Analysis revealed significant differences between conditions for both the learning and testing phases with the analogy condition demonstrating the lowest variability of the three experimental conditions in both segments. At first glance, this would seem to correspond to and possibly explain the lower standard deviation in technical efficiency for the analogy condition, but the

explicit light condition exhibited the greatest variability on average across all joints. Instead, the results suggest that the instructions differentially constrained movement, because of subtle differences in the way that the movement was described. For instance, the traditional explicit instructions indicated—through the use of the word straight—and the analogy instructions implied—through the scissor analogy—that knee angles should approach 180° at some point during the jump, whereas the explicit light condition never conveyed any specific information regarding the angle or positioning of either knee (see table 4.1 on p. 80). Without this information, participants in the explicit light condition could engage in more exploratory behaviour, resulting in greater knee joint variability, as shown in figure 4.6 (p. 88), while the movement of participants in the other two conditions was constrained by the task instructions.

Across conditions, joint variability generally decreased over the course of the learning phase, contrary to the predictions of dynamical systems theory. This could indicate a search for a preferred movement pattern early on—characterised by greater variability—with a gradual transition toward more stable coordination tendencies. This pattern did not hold for the task-relevant pressure test, however, as there was a significant interaction between condition, joint angle, and block for the testing phase. It could be that the high jump bar, which was introduced during the task-relevant pressure test, constrained movement as its height increased, no longer allowing the same freedom of movement afforded during the previous blocks of the study, a possible scenario that was discussed in the literature review (p. 40). It is also possible that the nature of joint variability changes as learning progresses. For instance, Hodges et al. (2005) found that range of motion in the hip initially

decreased for the first five practice sessions of a soccer chip shot task before reversing direction, while the opposite pattern was revealed for the degree of linear coupling between joints. Although the number of trials in this study were deliberately chosen to more accurately represent applied settings and limit fatigue, additional trials might have offered additional insight in this regard.

Possible explanations aside, the findings for all three experimental conditions with regard to joint variability offer limited support for Bernstein's (1967) predictions regarding the freezing and unfreezing of degrees of freedom. As Bernstein's hypotheses constitute a critical component of dynamical systems theory and related skill instruction models, the lack of empirical support could have significant implications for those interested in movement science. The results of this study do, however, correspond to constraints-led approaches regarding the nature of motor skill acquisition, which build upon concepts from Bernstein, dynamical systems theory and ecological psychology (Renshaw et al., 2009). From the constraints-led perspective, verbal information represents one of many constraints that interact with the individual characteristics of the learner, such as physical attributes and cognitive capabilities, to shape movement behaviour (Chow, Davids, Button, & Koh, 2008). For coaches, physical educators, and sport psychologists working in the field, the challenge, therefore, is selecting the most appropriate of these SOI to facilitate exploratory learning processes (e.g., Chow et al., 2007; Handford, Davids, Bennett, & Button, 1997; Komar et al., 2014). Although analogy instruction in this instance appears to have placed greater constraints on movement, further investigation is required to determine whether this finding is unique to this study or applies more generally.

Considering the results of the study as a whole, it appears that reducing the instructional volume has narrowed the gap between analogy and explicit learners, suggesting that the benefits previously ascribed to analogy could have been overstated. Lam et al. (2009b) argued that analogy's advantage lay in its implicit conveyance of instruction, citing the work of Wulf and colleagues on locus of attention (e.g., Wulf, McNevin, & Shea, 2001; Wulf & Shea, 2004) that demonstrates that focusing on even a single aspect of internal movement can disrupt performance. When explicit instruction matches analogy in its concision, however, it becomes unclear in what ways analogy distinctly benefits learners, especially in the face of research that shows that novices benefit from the skill-focused attention that is associated with explicit instruction (e.g., Beilock, Carr et al., 2002; Beilock, Wierenga et al., 2002). One of the strongest arguments for analogy learning may be that it could forestall skill failure at more elite levels of performance, although this would require a longer-term study comparing analogy and explicit methods that are matched in instructional volume or, perhaps, movement components. As it stands, analogy's greatest strength rests in its comparatively concise delivery, although there is limited evidence to suggest that it offers any inherent benefits over explicit instruction otherwise.

4.4.1. Future directions

The exclusion of two participants for disregarding instructions and instead relying on knowledge for separate, yet related skills presents a possible limitation that could have implications for not only this study, but much of the existing literature. In this regard, most of the research in analogy and explicit learning has

hinged on the assumption that the participants involved are complete novices without any previous knowledge or experience that could influence their movements or behaviours. However, in a review of motor learning research exploring the impact of focus of attention, Peh, Chow, and Davids (2011) noted that it could be unrealistic to assume that the preferred movement tendencies for a number of skills—even those that appear ostensibly novel—have not already been shaped by vicarious experiences or through personal participation in similar tasks. In this regard, the shortened, straightened, and less specialised run-up of the scissor jump technique could have permitted a transfer of skills or movement knowledge from other jumping-related skills (e.g., long jump, basketball lay-ups) that might not have been possible with the more complex and physically demanding approach required for the Fosbury Flop. In response, Peh et al. (2011) suggested the use of wholly unique movement tasks (i.e., novel tasks without any real-world equivalents) to minimise the effect of any previous experiences, although they also acknowledged that this approach could affect the generalisability of the findings to other movement skills. Rather than adjust the design of motor learning-related studies, a simpler and arguably more insightful approach, which was discussed in chapter 2, would be to recruit adolescent participants who would not only have fewer experiences upon which to draw, but would also better represent the students and athletes that might be learning such movement skills in the field. Although the recruitment of younger participants can add additional ethical and logistical challenges, their inclusion could serve to enrich or, perhaps, even transform current understanding of the impact of analogy and explicit instruction while simultaneously addressing difficulties regarding task novelty.

Going forward, it may also be time to finally abandon the traditional explicit condition, as long lists of instructions are unrepresentative of didactic methods in the field and conflict with recommended practice (e.g., McQuade, 2003; UK Athletics, 2009). As such, their continued inclusion limits the relevance and generalisability of empirical research to real-world situations, which helps neither researchers nor practitioners alike. While its inclusion in this instance helped to facilitate comparison with previous research, continually including a legacy condition that is unrepresentative and uninformative will likely constrain research design in future investigations.

4.4.2. Conclusion

By controlling the volume of information, performance for the explicit light condition was brought more in line with the analogy learners, relative to their traditional explicit counterparts, indicating that the advantages ascribed to analogy learning might not be as pronounced as previously believed. It could still be that analogy learning promotes learning that is ultimately more robust to performance pressure in elite performers, but additional study will be required to distinguish the properties or qualities of these instructional types that engender such learning and performance benefits earlier in the skill acquisition process. Kinematic analyses failed to support Bernstein's (1967) original proposals regarding the freezing and gradual releasing of biomechanical degrees of freedom, although they did suggest that movement may vary with respect to the provided instructional information, which may hold important implications for researchers in human movement studies with an interest in dynamical systems and constraints-led approaches. The results

from this study raise questions regarding analogical and explicit instruction—from both theoretical and applied perspectives—that warrant further investigation.

Chapter 5. The impact of analogy and explicit instruction on adolescent motor learning

Chapter Aims

As discussed in chapter 2, evidence suggests that the nature of motor learning and performance differs with respect to age or factors associated with age. Employing a modified high jump task once more to facilitate comparison with the previous study, this chapter sought to investigate the differential effects of analogy and explicit instructions on adolescents for the first time. Movement and performance were again assessed using similar measures to those in chapter 4. Together with the previous chapter, this study was intended to offer additional guidance to practitioners working in the field regarding the impact of analogy and explicit instructions.

5.1. Introduction

To date, research investigating the differential effects of analogy and explicit instructions on movement and performance has concentrated solely on their impact upon adults. As discussed in chapter 2 (section 2.9.5), however, there is a growing body of evidence that suggests that there are differences in motor and cognitive processes between adults and adolescents. For instance, Sullivan et al. (2008) observed that the effects of KR in an arm movement task differed with respect to age. For the children in the study, they performed best with feedback following every trial, while the adults were best when feedback was received only intermittently. Adolescents have also demonstrated distinct information-processing (e.g., Pollock & Lee, 1997; Wade, 1976) and cognitive capabilities (e.g., Tipper et al., 1989; Yuzawa,

2001), which could limit the generalisability of motor learning findings from adults to adolescent populations (Sullivan et al., 2008). As analogy and explicit learning involve both cognitive and movement aspects, understanding how age might moderate the effects of analogy and explicit instructions represents a meaningful line of research, especially as younger participants would also better represent the student and athlete populations that are actively engaging in such motor learning on a day-to-day basis.

Extending the investigation of analogy and explicit instruction to adolescents would have additional benefits as well. In chapter four, reducing the volume of information in the explicit light condition appeared to mitigate the negative effects associated with traditional explicit instructions in motor learning situations; however, there were concerns regarding task novelty. In this regard, two participants were excluded for relying on personal knowledge of related skills and disregarding the task instructions. To date, a fundamental premise of much of the research in analogy and explicit instruction has been that the participants were inexperienced and lacked any previous knowledge regarding the to-be-learned movement skills. Peh, Chow, and Davids (2011), however, argued that it might be unreasonable to assume that movement preferences for a variety of skills have not already been shaped by participation in similar tasks or, alternatively, through vicarious experiences. The exclusion of these two participants suggests that task familiarity could represent a pervasive methodological issue affecting motor skill research. The inclusion of younger participants would minimise the possibility of previous experiences influencing movement, as adolescents would have fewer experiences upon which to act. Consequently, the recruitment of younger participants would address concerns

regarding task novelty and offer greater insight regarding the effects of analogy and explicit instruction on movement and performance.

5.1.1. The current study

The primary aim of the current investigation was to explore the differential effects of analogical and explicit instruction on movement and performance in adolescents. The modified high jump task was employed once again not only because it is well suited to analogy and offers a controllable task-relevant pressure (i.e., bar height), but also to facilitate comparison to the preceding study. The traditional explicit group, which had been included in the previous study, was not included in this instance, as long, prescribed lists of instructions are inconsistent with recommended coaching practice, as discussed at the conclusion of chapter 4.

As the impact of instructional type on coordination during movement also represents an important consideration for athletes, students, coaches, physical educators, and sport psychologists, the effects of analogy and explicit instruction were again explored from a dynamical systems theory perspective during the task-relevant pressure test. A secondary aim of the study, consequently, was to explore whether analogy or explicit instruction differentially affected the nature of joint variability in the performance of the scissor technique. In the preceding study, joint variability varied with respect to instructional type, as the analogy learners demonstrated significantly less variability around the joints than either of the explicit conditions. It was of particular interest to see if this pattern changed or remained the same for the adolescent participants. Unfortunately, because the location of this study was moved from the University laboratory to a local school, there were

significant temporal and logistical constraints that did not permit filming of the learning phase as planned for kinematic analyses. These constraints also prevented the collection of heart rate and verbal protocol questionnaire data, which had been recorded in chapter 4. Despite these issues, the chance to conduct this research in a real-world setting with adolescent participants represented a unique opportunity to gain additional insight into the differential effects of analogy and explicit instruction.

5.2. Method

5.2.1. Participants

Fourteen healthy adolescent male students (mean age = 12.7 years, $SD = 0.4$) from George Watson's College in Edinburgh, Scotland volunteered for the three-day study (see table 5.1 for participant information). In all instances, consent was obtained from both the volunteers themselves and their parents. Participants, who attended in groups of four to better represent competitive conditions in the task-relevant pressure test, were assigned to one of two experimental conditions: the analogy condition ($n = 7$) and the explicit condition ($n = 7$). Due to the nature of conducting research in a real-world school setting, ten participants withdrew from the study for myriad reasons including illness, unintended absence, and injury (unrelated to this research) over the course of data collection. The study was administered with the consent and collaboration of the school senior management and physical education department. To conduct the research, the school offered a data collection window of eight weeks with three sessions weekly. These epochs of data collection coincided with full school timetables. Prior to commencing the study, a Protecting Vulnerable Groups (PVG) disclosure clearance was obtained from

Disclosure Scotland and approval for the study was granted by the University of Edinburgh School of Education ethics committee.

Table 5.1. *Participant Demographics*

	Age (years)		Height (m)		Weight (kg)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Analogy	12.48	0.40	1.57	0.03	48.21	7.55
Explicit	12.91	0.23	1.57	0.08	49.50	6.64

5.2.2. *Apparatus and task*

Participants learned and practised the scissor-style technique in a purpose-built gym hall at the Centre for Sport at George Watson’s College in Edinburgh. As in the previous study, a rectangular ‘take-off’ area was marked on the floor in front of the landing mats to control both the length and angle of the approach. The approach run was once more restricted to two steps to promote a sense for the rhythm, technique, and body positioning required for the high jump (American Sport Education Program, 2008; Otte, 1999), without needing the speed and strength that the curved, full-length approach would demand. As before, only left-side run-ups were permitted (i.e., right-foot take off) due to space and equipment constraints, but this was not anticipated to affect learning or performance in the task, as research has demonstrated similar leg kinematics between dominant and non-dominant legs in jumping tasks (van der Harst et al., 2007).

For the kinematic analysis, three Panasonic digital video cameras (Panasonic

HC-V100) recording at 50 fields per second filmed the jumping trials of the participants. The placement and positioning of the cameras, the mats, the high jump standards, and the run-up area directly corresponded to their positions in chapter 4, as shown in figure 4.2 (p. 77). Custom-built vertical rods were used to calibrate the image space (3.31 m \times 2.09 m \times 2.43 m) before the start of the testing phase (Coleman & Rankin, 2005). Eighteen body landmarks were manually digitised, transformed into three-dimensional coordinates (Abdel-Aziz & Karara, 1971), and then smoothed using the APAS motion analysis system (Ariel Performance Analysis System; Ariel Dynamics, Inc.; San Diego, CA, USA).

5.2.3. Design

The experiment followed the precedent of the previous study with a two-day learning phase and a one-day testing phase. For each day of the learning phase, participants performed 2 identical blocks of 10 jumps. For the testing phase, there were two parts: a retention test and a task-relevant pressure test. During the retention test, participants once more performed 10 jumps. For the task-relevant pressure test, however, participants continued jumping until they recorded three successive failures in accordance with the competition rules of the high jump. In all instances, there were 47 hours separating each session (i.e., they attended for one hour at the same time every other day).

5.2.4. Procedure

Using the instructions for their respective conditions, participants learned and performed the scissor-style high jump technique by jumping over a foam-covered,

low-height elastic band held in position by two uprights. During the task-relevant pressure test, the elastic band was replaced by a 4-m regulation-length high jump bar, which was raised 5 cm after each successful clearance. As in the previous study, participants were informed that they must always land upright (i.e., on one or both feet) and that they could only use the designated run-up area for their approach and jump. Before the start of each session, participants warmed up with dynamic stretching exercises, as in the preceding study, based on Ebben and Petushek (2010). Participants received 40 s rest between all jumps throughout the study.

The instructions for the two experimental conditions matched the instructions given to the analogy and explicit light participants in the previous chapter, as shown in table 5.2 (p. 112). Before commencing each block of jumps, participants were asked to read through the instructions for their respective conditions. For the testing phase, participants were not reminded at any point of their instructions and were simply asked to maintain effort and perform at their best (Lam et al., 2009b). The technique was styled in this instance the ‘Oregon State style high jump technique’ to mitigate the possibility of any possible prior knowledge or awareness of the scissors style affecting participant performance.

Unlike the previous study, participants attended in groups of 4 to better represent real-world competitive conditions during the task-relevant pressure test. During the learning phase and the retention test, however, participants were prohibited from viewing the trials of others in their cohort, lest they should influence each other’s performances. For the task-relevant pressure test, trials were deemed successful only if the participants both jumped over the bar without dislodging it (i.e., the bar stayed on the standards) and landed upright on the mats.

Table 5.2. *Instructions for the Experimental Conditions*

Condition	Instructions
Analogy	Keep your upper body tall like a pencil through takeoff Alternate your legs like scissors to clear the bungee cord
Explicit	Keep upper body tall through takeoff Lift left leg up over the cord and bring down Repeat action with right leg

5.2.5. *Dependent variables*

5.2.5.1. *Psychological measures*

Subjective anxiety was measured at the end of the learning and testing phases using the anxiety thermometer (Lam et al., 2009a; Pijpers et al., 2005; Pijpers et al., 2003). Participants were asked to rate their current level of anxiety by placing a cross on a 10-cm continuous scale, ranging from 0 (left end; not anxious at all) to 10 (right end; extremely anxious). The measure of self-reported anxiety was the physical distance between the left edge of the scale and the participants' markings.

Self-reported mental effort was assessed using the RSME (Zijlstra, 1993) at the conclusion of both the learning and testing phases. In each case, participants were asked to rate the amount of effort invested during performance on a vertical axis scale ranging from 0–150. Nine separate category descriptors detailed the points throughout the continuum, including 3 (no mental effort at all) and 114 (extreme mental effort) at the extremes.

5.2.5.2. Technical efficiency

Following the design in the previous chapter, a standardised measure of technical efficiency ($\text{COM}_{\text{peak}} \div \text{bar height}$) was used to evaluate the technical efficiency for each participant, inspired by the methods of Hay and Reid (1982) and Dapena (1992). As before, higher ratings represent more efficient clearances, while lower ratings indicate less efficient clearances during which the jumping technique limited the maximisation of flight height.

5.2.5.3. Joint variability

To investigate the impact of instructional type on movement, standard deviations around the mean (Glazier, 2011; Vereijken et al., 1992) were calculated for the left knee, left hip, right knee, and right hip for each participant's best clearance during the task-relevant pressure test. As in chapter 4, these particular joints were chosen based on biomechanical analyses of high jumping (Dapena, 2000; Dapena et al., 1990; Greig & Yeadon, 2000) and the technical requirements of the scissor technique (American Sport Education Program, 2008; P. Reid, 2010). In all instances, data were transformed into CV prior to analysis in order to facilitate comparisons between and across joints and to eliminate the mean differences between individuals (James, 2004; Lam et al., 2009b).

5.2.6. Analyses

Kinematic analysis began seven frames (0.14 s) prior to the moment that the jumping leg contacted the floor to initiate the jump and ended immediately upon contact with the mats at the completion of the jump, corresponding to the analysis

conducted in the previous chapter. This permitted analysis of the touchdown, takeoff, and flight phases of the jump. Any data that failed to meet assumptions of sphericity were corrected using Greenhouse–Geisser procedures (Field, 2005). As the APAS biomechanics package calculates kinematics using adult body segment parameter data (Dempster, 1955), which cannot be extrapolated to children (Jensen, 1989), age-based regression equations by Jensen (1986) were employed to obtain body segment parameter data for the adolescent participants. Research suggests that these equations represent a suitable alternative to more extensive anthropometric imaging techniques, such as MRI (Bauer, Pavol, Snow, & Hayes, 2007). Unless otherwise noted, Bonferroni's method was used for all post hoc analyses in order to control for type I errors (Field, 2005). All results reported as significant at the .05 level.

5.2.7. Digitising accuracy and precision

To evaluate digitising accuracy, a moving 200-mm rigid segment was digitised using the same method as in the experimental analyses (Salter et al., 2007; Wormgoor et al., 2010). In line with previous research (Challis, 1997; Coleman & Rankin, 2005), the mean reconstructed length of the segment measured 201 mm \pm 2.1 with a mean error of 1 mm (0.05%). With regard to digitising precision, a specific jumping trial was digitised six separate times (Challis, 1997; Coleman & Rankin, 2005) and, based on these data, typical errors were then calculated (Hopkins, 2000). The process of repeated digitisation yielded typical errors for the COM of ± 4 mm, ± 2 mm, ± 3 mm in the x , y , and z axes, respectively.

5.3. Results

5.3.1. Technical efficiency

To determine whether there were any differences in technical efficiency with respect to instructional type, an independent t-test was run on data derived from the highest clearance for each participant during the task-relevant pressure test. Although participants from the analogy group demonstrated marginally better efficiency ($M = .77$, $SD = .044$, $SE = .017$) on average than their explicit counterparts ($M = .74$, $SD = .053$, $SE = .020$); these differences were not statistically significant overall, $t(12) = 1.152$, $p = .272$, $r = .32$. These data are shown in figure 5.1 (p. 116).

5.3.2. Joint variability

To investigate joint variability, a 2×4 (Group \times Joint Angle) mixed design ANOVA was run on the CV data from the highest clearance for each participant. Prior to analysis, the CV figures were square root transformed to ensure the normality of the distribution and to facilitate comparison with the previous chapters. There were no significant between-group differences, $F(1, 12) = .046$, $p = .835$, $\eta_p^2 = .004$, indicating that variability in the joints did not differ with respect to instructional type, as depicted in figure 5.2 (p. 116). In fact, mean variability across joint angles was remarkably similar for both the analogy ($M = .50$, $SD = .10$, $SE = .02$) and explicit conditions ($M = .50$, $SD = .09$, $SE = .02$). Results also revealed a within-subjects effect for joint angle, $F(3, 36) = 22.286$, $p < .001$, $\eta_p^2 = .65$. Participants exhibited the least variability in the right knee ($M = .40$, $SD = .09$, $SE = .02$) and demonstrated the greatest amount of variability in the left hip ($M = .59$, $SD = .05$, $SE = .01$), as figure 5.3 (p. 117) shows.

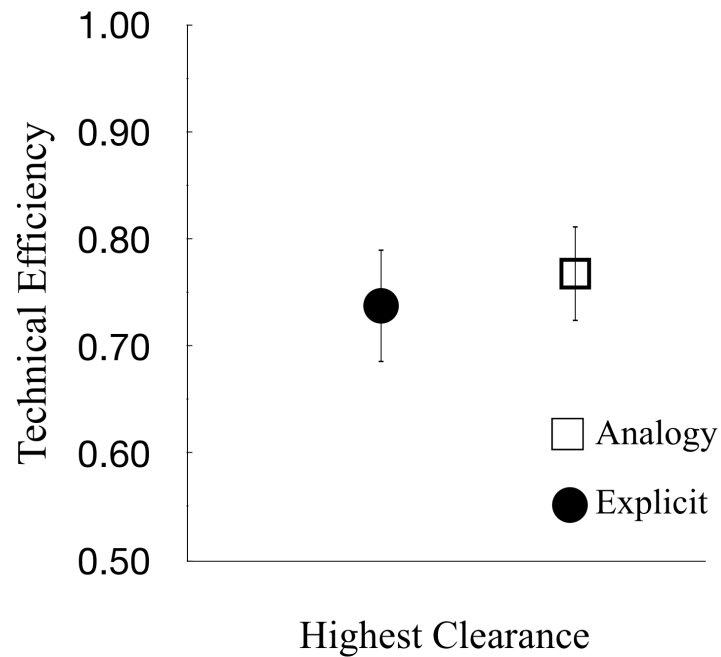


Figure 5.1. Mean technical efficiency during highest bar clearance in the task-relevant pressure test as a function of condition. Error bars show standard deviation.

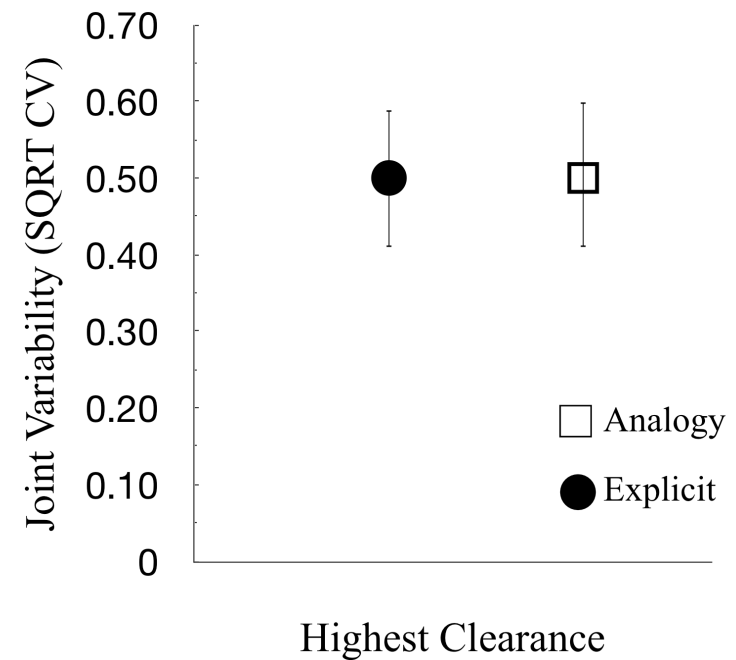


Figure 5.2. Mean square root transformed CV values averaged across joints for the highest bar clearance during the task-relevant pressure test. Error bars show standard deviation.

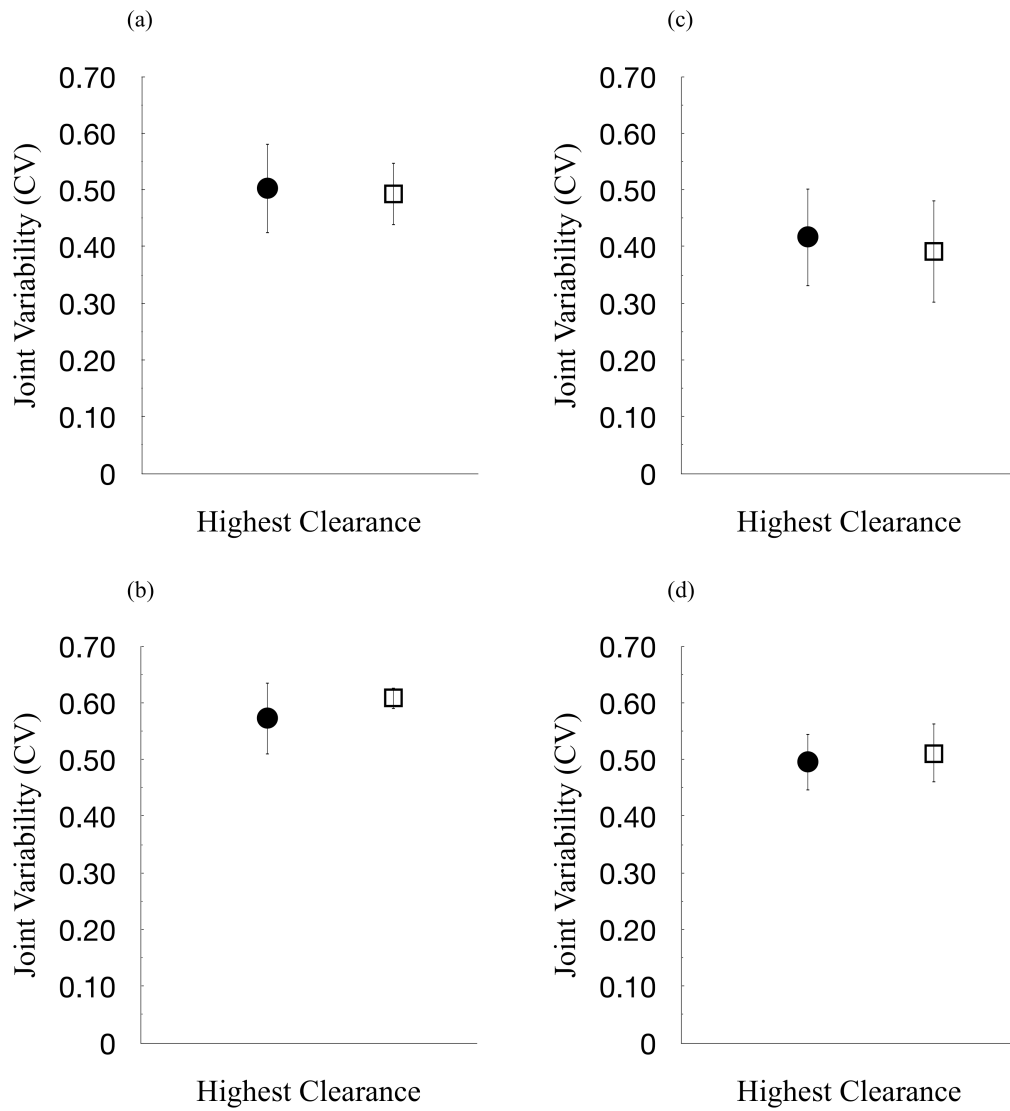


Figure 5.3. Mean square root transformed CV values as a function of condition for the highest bar clearance in the task-relevant pressure test. (a) Left Knee (b) Left Hip (c) Right Knee (d) Right Hip. ● – Explicit, □ – Analogy

5.3.3. Effectiveness of Pressure Manipulation

To investigate the effectiveness of the pressure manipulation, a 2×2 (Group \times Block) MANOVA with repeated measures on the latter factor was conducted on anxiety thermometer and RSME data from the conclusion of both the learning and testing phases. Analysis revealed a significant within-subjects effect for block, $F(2, 11) = 17.239, p < .001$, due to increased ratings of self-reported anxiety and effort in the testing phase, suggesting that the pressure manipulation was successful. Multivariate analysis did not indicate a significant between-subjects effect, $F(2, 11) = 1.899, p = .196$. These data are presented below in table 5.3.

Table 5.3. *Comparison of Anxiety Thermometer and RSME*

	Last Learning Block		Task-Relevant Pressure Test	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Anxiety Thermometer *	1.71	0.39	4.67	0.65
Rating Scale for Mental Effort *	57.57	8.11	101.93	8.28

* Difference between blocks significant at $p < .001$ level

5.4. Discussion

As there is evidence that adults possess distinct cognitive and motor capabilities compared to adolescents, which could influence movement mechanics and their interpretation of any verbal instructions, the aim of the current study was to investigate the effects of analogical and explicit instruction on adolescents. To

accomplish this, the efficiency of the scissor technique was examined for the highest bar clearance during the task-relevant pressure test for each participant. Although the analogy condition was marginally more efficient on average, the results did not reveal any statistically significant differences between the analogy and explicit conditions. In fact, the two conditions demonstrated remarkable similarities, even with regard to highest clearance height and other kinematic measures (see table 5.4 on p. 121), largely corresponding to the findings for technical efficiency from the previous study. Like the previous study, however, it is possible that underlying differences were diminished or obscured by the well-controlled experimental set up, which could have reduced the participants' reliance on the instructions in their search for an effective coordination solution. In this regard, the marked run-up area and height of the bar could have constrained movement to such a degree that any differences in technical efficiency that the task instructions might have potentially produced were effectively masked or eliminated.

The secondary aim of the study was to explore differences in joint variability to determine how verbal instructional type might differentially affect movement kinematics. Echoing the findings for technical efficiency, there were also no statistically significant differences found between conditions for joint variability, as both analogy and explicit learners exhibited corresponding levels of variability between and across joints. While joint variability in adult participants differed with respect to verbal instructional type in chapter 4, it is interesting that variability for adolescent participants in this study did not vary. This finding suggests that verbal instructions could differentially affect adult and adolescent learners, corresponding with the findings of Sullivan et al. (2008). If this is so, from a scientific perspective,

this finding has major implications for research with regard to participant recruitment and the generalisability of findings using adult samples, for example. It cannot be ruled out, however, that diminished task familiarity compared to adult participants may have also contributed to the differences between the adult and adolescent learners in chapters 4 and 5, respectively. The impact of the heavily controlled experimental set up must also again be considered, as it is possible that the task constraints, such as the run up area, high jump bar, or task rules, did not afford participants the freedom to ever even demonstrate any differences in joint variability in the first place. No matter the interpretation of these results, however, some restraint is advisable regarding these findings and their comparison with the previous chapter, as kinematic data were not collected during the learning phase in this instance due to the logistical and temporal constraints of working in the real-world school setting. As it stands, this particular study measured *performance* following a learning phase, but not necessarily learning itself, so understanding regarding the implications for adolescent motor learning will likely require additional study to confirm these effects.

From a practical perspective, these findings do suggest, however, that analogy instruction may not necessarily be any more helpful than explicit instructions for adolescent performance. Curiously, a practical instruction guide for physical educators working with disabled individuals (Lieberman, Ponchillia, & Ponchillia, 2012) had previously suggested that analogy-based instruction might prove more useful for adults, as they have more ‘life experience on which to draw comparisons’ compared to adolescents, but this possibility had been overlooked by researchers

Table 5.4. Comparison of Mean Values for Highest Clearance During Task-Relevant Pressure Test as a Function of Condition

	Highest Clearance (m)		Technical Efficiency		COM _{td} (m)		COM _{to} (m)		COM _{peak} (m)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Analogy	1.01	0.10	0.77	0.04	0.80	0.03	1.10	0.07	1.32	0.06
Explicit	0.97	0.11	0.74	0.05	0.82	0.04	1.07	0.07	1.32	0.09

COM_{TD} refers to the height of the COM at touchdown when the jumping leg first contacts the floor to initiate the jump.

COM_{TO} represents the height of the COM at takeoff, the moment that the jumping leg loses contact with the floor.

COM_{peak} is the COM at the maximum height of the jump.

until this study. This development could potentially extend additional support to the argument in chapter 3 that coaches and sport psychologists may wish to investigate alternative SOI for structuring or planning the development of motor skills rather than rely solely on verbal information.

5.4.1. Future considerations

The potential effects of task novelty and the differences in joint variability between the adult and adolescent participants in the past two chapters raise interesting questions surrounding experimental design in future physical education, sport psychology, biomechanics, and other performance-related research, as the recruitment of adolescents to circumvent such difficulties may be unrealistic in many cases. In fact, in the case of this study, not only was participant recruitment difficult, but so was participant retention. While the recruitment of younger participants may provide opportunities for more meaningful data in some respects (e.g., more representative sample and location), their inclusion can introduce additional barriers that must be carefully considered and balanced alongside the aims of the research. Between busy academic, sport, and activity schedules, working with active children can pose considerable constraints, not to mention ethical and administrative concerns.

Leaving to one side unavoidable logistical limitations associated with the present study, Peh et al. (2011), in a review of attentional focus research, suggested that individual analyses may overcome issues relating to task novelty, as such approaches would take into account individual rates of skill development. Unfortunately, this suggestion would offer little assistance if the nature of motor

learning and movement differ in adults and adolescents. For researchers, there is unlikely to be a perfect solution to this issue; consequently, researchers may need to look for the best methods to minimise potential difficulties on a case-by-case basis. For applied practitioners, adopting an approach based on the needs and characteristics of the individual, rather than simply applying an approach from the literature to that individual could represent the most effective method with regard to instruction.

In terms of research design, it could also be time to entirely rethink the standard research paradigm in this area, as coaches typically do not provide learners with fixed, unchanging sets of instructions to learn over the course of several days. While these heavily controlled designs are necessary to establish an initial understanding of the effects of verbal instruction, subsequent studies must begin to give way to the real-world issues faced by performers and coaches. The incorporation of more modern measurement and analysis technologies may also help in this endeavour, as the methods of analysis in analogy and explicit learning research have remained largely unchanged over the years, despite considerable technological advancements in measurement techniques that have fuelled development in other areas of skill acquisition and coordination research (Hodges et al., 2005).

5.4.2. Conclusion

Extending the investigation of analogy and explicit instructions to adolescents, differences between the analogy and explicit conditions with regard to technical efficiency and joint variability were statistically non-significant. These results largely

correspond to the findings of the previous chapter and also support the hypothesis that the movement and cognitive processes implicated in motor learning may differ with respect to age and experience. While issues arising from the real-world physical education setting and its associated constraints mean that conclusions drawn from this chapter should be considered carefully, the implications are practically meaningful and undoubtedly justify further empirical research.

Chapter 6. General Discussion

Chapter Aims

This chapter synthesises, examines, and discusses the research findings presented in chapters 3–5. To start, this chapter restates the aims of the thesis and summarises the key empirical findings. The limitations of the research are then examined, before discussing the implications of the findings from both theoretical and applied perspectives. In this discussion, recommendations for applied practitioners, coaches, and physical educators working in the field are also presented. From here, suggestions for future investigations are provided, followed by the overall conclusions of the thesis.

6.1. Restatement of aims and objectives

The primary aim of this thesis was to investigate and appraise the utility of analogy and explicit instructional sets for applied sport and physical education settings. In recent years, analogy learning has become a fashionable instructional alternative to traditional step-by-step instructional methods as it is thought to promote implicit learning processes that forestall skill failure under pressure. Unfortunately, previous investigations had only compared analogy and explicit instructions within a narrow set of parameters that did not necessarily reflect the diverse and varied sporting and education environments within which students, athletes, coaches, physical educators, and sport psychologists inhabit. For sport psychologists, who will likely work with coaches, as well as sports people, understanding the implications of verbal communication in learning and performance

contexts between these groups represents useful knowledge for informing practice. Likewise, for physical educators, who will be working with students to teach and refine a number of diverse skills, these implications are equally as critically. In undertaking this research, the objective was to address the gaps in the existing literature to offer additional guidance and practical advice to sport psychologists and others working in the field.

6.2. Summary of findings

In chapter 3, the first study of the thesis examined the acute effects of explicit and analogy instruction on motor control in a dart-throwing task. Twenty novices performed 72 total trials—both with and without KR—in baseline, analogy, and explicit conditions. Participants were most accurate in the baseline conditions regardless of the presence—or absence—of KR. Although performance in the experimental conditions was significantly lower than the baseline conditions, accuracy scores in the explicit condition were marginally higher on average than those in the analogy. In all cases, participants demonstrated greater accuracy when KR was available. Kinematically, participants in the baseline conditions exhibited significantly less joint variability and throw duration, but greater maximum elbow flexion and angular velocity than they did in the explicit and analogy conditions. These findings suggest that explicit and analogy instruction—in acute contexts—may slow and disrupt movement execution.

These effects of analogy and explicit instruction on motor control offer limited correspondence with previous findings in the literature regarding their effects in motor learning situations. In those earlier studies, however, the number of explicit

rules has always outnumbered the analogy instructions. To address concerns regarding the differential demands on attention with respect to instructional type, the second study, reported in chapter 4, introduced an explicit condition with reduced informational volume. Over the course of a two-day learning phase and single-day testing phase, participants learned and performed a modified high jump task using one of three types of instruction: analogy, explicit light (reduced instructional load), and traditional explicit (typical instructional load). While pressure in earlier investigations had typically been evoked using artificial manipulations, this study employed the task-relevant pressure of bar height in order to evaluate technical performance. On average, participants in the analogy condition demonstrated the most efficient and most consistent technique than either of the explicit conditions, although these differences were not statistically significant. Results for joint variability suggest that participants in the explicit light condition engaged in more exploratory learning, as they demonstrated significantly more variability across all joints during the learning and testing phases of the study. The analogy learners exhibited the least variability of the three instructional groups, which was likely due to the scissor instruction providing more information regarding the angle of the knee joints than in the other two conditions. Across all groups, however, joint variability decreased as a function of learning, which was counter to expectations based on Bernstein's (1967) predictions regarding the freezing and freeing of degrees of freedom.

The third study—detailed in chapter 5—examined the effects of analogy and explicit instructions on adolescent learners for the first time. To facilitate comparison to adults, participants once again learned and performed a modified high jump

technique over three days. Although the analogy participants demonstrated more efficient technique on average for their highest clearances, these differences were non-significant, mirroring the findings from the study in chapter 4. Unlike the previous study, however, there were no differences between the explicit and analogy conditions in joint variability for the participants' highest clearances. In fact, kinematically, the participants from both groups were remarkably similar. These results correspond with findings in the cognitive psychology and motor learning literature, as the differences in the effects of analogy and explicit learning appeared to vary with respect to age. Considering these findings with those of the adults in chapter 4, the results of this third study suggest that the advantages ascribed to analogy instruction in the literature might have previously been overstated. Due to constraints associated with the working in the real-world school setting, however, there were no kinematic data collected during the learning phase, only the testing phase, so it is still possible that understanding regarding the impact of analogy and explicit instruction on adolescents remains incomplete and will likely require further investigation.

6.3. Theoretical implications

Considering the thesis in its entirety, there are several important theoretical implications that emerge from the findings. While the previous literature suggests that the instructional type itself is the key factor affecting performance, the results from this thesis indicate that there may be several factors that moderate the effects of verbal instruction. The first of these potential moderators is the proximity of the delivery to the task it describes. Although research has demonstrated benefits in

using analogy instruction in motor learning contexts over many trials (e.g., Poolton et al., 2006, 2007b), the results reported in chapter 3 suggest that verbal information may negatively impact performance in short-term, motor control situations. Unfortunately, it is unclear how long these negative effects of the verbal instructions may persist. It might also be possible that these short-term effects associated with the delivery of verbal instruction might also have impacted performance in earlier studies, but these effects were obscured by the outcome-focused measures. Given the prevalence of verbal instructions in sport and physical education, however, the proximity of delivery to performance represents a factor that coaches, educators, and sport psychologists may need to carefully (re)consider whenever they are compelled to convey movement information to performers or students.

Another likely moderator of the effects of analogy and explicit instruction is the volume of that instruction. As attention-based theories have emerged as the most likely explanations of the choking phenomenon (Hill et al., 2010), it is curious that researchers did not think to match the attentional loads of the analogy and explicit instructions in earlier studies. When this informational disparity was controlled, explicit instruction in this thesis did not significantly impair performance compared to analogical instructions. Analogy participants did demonstrate slightly more efficient technique, however, in both of the high jump tasks, so volume may only constitute one of several qualities of verbal instruction that can influence performance. As mentioned in chapter 4, the number of movement components described in the instructions may represent another of these characteristics. Although movement mechanics in the analogy and explicit conditions were similar in chapters 3 and 5, the adult participants in the high jump task of chapter 4 did exhibit

differences in joint variability with respect to instructional type. In this regard, the explicit light condition demonstrated the highest levels of joint variability of the three conditions during both the learning and testing phases, while the analogy learners displayed the lowest. Because this pattern was not observed in the adolescent participants, this suggests a factor associated with age must have moderated the effects of these instructions.

One possibility that was discussed earlier in the thesis is that adolescents may not have already formed preferred movement tendencies to transfer into these new tasks, as they have fewer experiences upon which to draw. Adults, on the other hand, are likely to have personal or vicarious knowledge of the task—or similar tasks—that influence how they respond to the instruction (Peh et al., 2011). Research has shown, however, adolescent cognitive process such as selective attention (Tipper et al., 1989) and verbal learning (Yuzawa, 2001) to be distinct from those of adults, which could also have contributed to differences between adult and adolescent participants in this thesis. From an ecological psychology perspective, children are thought to operate linguistically within a narrower range of a language's variability (Reed, 1996), so differences in movement mechanics could have been diminished due to less variation in the interpretation of any instructions. Regardless of the precise theoretical explanation, the possibility that younger learners interact differently with the same instructions as adult learners has significant implications for—and potentially imposes significant constraints on—future research in this area. While studies featuring adolescent participants present meaningful opportunities to enrich understanding, ethically and logistically their inclusion can constrain research

design. If the goal of the research is to inform sport psychology, physical education, or coaching practice, however, this is an issue that researchers will need to address.

There are also important theoretical implications for Bernstein's (1967) hypotheses regarding the freezing and freeing of degrees of freedom, as joint variability in the study reported in chapter 4 actually decreased for all instructional conditions as a function of learning, contrary to Bernstein's predictions. These findings do correspond however, with previous research from a dynamical systems theory perspective that the nature of movement learning may actually be task dependent and not fixed as part of a universal motor learning strategy (e.g., Ko et al., 2003; Newell, 1996; Newell & McDonald, 1994; Newell & Vaillancourt, 2001). At the very least, it would seem that Bernstein's hypotheses require revision to account for the research of this thesis as well as the data collected by Newell and colleagues,

That said, it is also important to note that joint variability did not simply decrease with learning, but the degree of variability significantly differed with respect to instructional type in chapter 4. The findings suggest that the nature of joint variability may also vary with respect to discrete characteristics of the instructions themselves and not necessarily the type of instruction. In this regard, the explicit light participants demonstrated the most variability between the three conditions not because their instructions were explicit, but likely because those instructions did not specifically provide or imply any information regarding the angle or positioning of the knee, unlike those for the analogy and traditional explicit conditions. According to Bernstein (1967), however, the role of verbal instruction in motor skill acquisition is minimal; instead, adaptive perceptual-motor skills should primarily emerge implicitly through the interaction of various constraints on movement, as discussed

in the literature review. This perspective would explain how children can quickly acquire new movement skills with little parental guidance or instruction (Davids et al., 2008), but cannot necessarily account for the differences observed between the experimental conditions in chapter 4.

Although verbal instruction has not represented a primary theoretical or research consideration from a dynamical systems theory perspective, the constraints-led approach, which emanates from dynamical systems theory (Renshaw et al., 2009), regards verbal communication as a possible temporary informational constraint for regulating movement (Davids et al., 2008). While research indicates that learners couple movements with perceptual information and not words (Gibson, 1979), verbal instruction may help to facilitate the search for relevant perceptual information to optimise coordination solutions (Davids et al., 2008). According to Davids et al. (2008), verbal instructions can be used to clarify task goals and provide ‘shortcuts’ for exploring specific aspects of the perceptual-motor environment. Approaching their research from a constraints-led perspective, Komar et al. (2014) compared the effects of an internally focused analogy instruction to control conditions in a breaststroke-learning task from a constraints-led perspective. Although there were no statistically significant differences in swimming speed or stroke rate between the analogy and control conditions, the analogy participants did show a greater increase in swimming efficiency (i.e., coordination of the arms and legs were closer to anti-phase). The element that research from this constraints-led perspective—and any future research involving verbal instruction—may need to consider, however, is how verbal instruction—whether explicit or analogical—can promote the search for useful perceptual information. In the research, to date, the

instructions have simply described the intended movement goals to participants rather than aiming to identify the information that would prove most valuable for attaining these movement-oriented goals, which ultimately might prove more useful for coaches, physical educators, and sport psychology practitioners.

6.4. Practical implications

While the theoretical implications of the findings from this thesis are important, the practical implications for sport psychologists, coaches, and physical educators in real-world settings represented a primary concern. As traditional skill teaching methods ordinarily emphasise the use of verbal instruction to direct learners toward idealised skill models (Davids et al., 2008), comprehensive understanding of the effects of verbal instructions constitutes a key consideration. While much of the literature has championed analogy instruction as a verbal means of facilitating implicit learning and communicating information, the results from this study offer limited support for this perspective. If performance is imminently important, the findings of chapter 3 suggest that sport psychologists, physical educators, and coaches should limit their use of verbal instructions. During all of the verbal instruction conditions, dart-throwing accuracy decreased, while throw duration and joint variability increased, compared to baseline conditions. Although coaches, physical educators, and sport psychologists should be careful when extrapolating these findings to expert or elite populations, the findings are unsupportive of unfamiliar verbal instructions in motor control situations involving novices. While Gabbett and Masters (2011) mention that rugby league coaches are often tempted to ‘fast track’ player development by using verbal instructions, the findings in this

thesis suggest that coaches, physical educators, and sport psychologists should carefully consider the nature of their communications with athletes. While research suggests that verbal cues—mutually shared by coaches and athletes—that represent deeper knowledge structures may benefit experienced performers (e.g., Toner & Moran, 2011), new instructions provided in close proximity to competition to inform or reshape movement may be problematic.

With regard to applied motor learning contexts, there is limited evidence to support the use of analogy instruction over explicit methods. Although the findings of this thesis cannot conclusively rule out the possibility that analogy might still possess some advantages over explicit methods in specific circumstances, the advantages appear less obvious than previous research would indicate. Moreover, recent evidence suggests that conscious processing, which is thought to be engendered by explicit instruction, does not necessarily result in impaired performance and may actually benefit experts looking to refine technique (Toner & Moran, 2011). Indeed, Toner and Moran (2014) argue that the premise of selecting instructional methods designed to address a single phenomenon (i.e., choking) is short-sighted, inflexible, and potentially harmful, as the demands and requirements of skilled performers change dynamically throughout competition and across seasons. Applied sport psychology practitioners, coaches, and physical educators may instead wish to consider using the instruction that succinctly provides the most relevant information for achieving specified short-term or long-term goals rather than preferring any one verbal instructional type to another.

A major obstacle that requires further attention is the shared understanding of movement instructions between instructors and learners. According to Reed (1996),

‘identical language is never found in two people’ (p. 165), which can mean that instructions that have a specific, relevant meaning to the instructor might signify something else entirely to the learner. Analogies, in particular, are culturally and contextually specific (Roessger, 2012) and can even create the illusion of comprehension where little actually exists (Jaeger & Wiley, 2015). In fact, in an unpublished study, Poolton, Masters, and Maxwell (2003) found that the same table tennis analogy that had been effective with English speakers (e.g., Liao & Masters, 2001)—in comparison to explicit methods—proved ineffective with Chinese-speaking participants. As reported in chapter 3, there was even considerable variation in the interpretation of the ‘move your arm like a catapult’ instruction, with some participants mimicking the motion of the basic, ancient tension-driven catapult device, as intended, while others imitated the movement of a trebuchet, the counterweight-dependent, mediaeval siege weapon. These instances illustrate that even the same analogies may prove differentially effective depending on the learner, their circumstances, and, as demonstrated in chapter 3, participants’ insights into mediaeval warfare. What may be especially critical for applied work, therefore, is not necessarily the type of verbal instruction, but the significance of that instruction to the learner and the connections that they are able to make, internally and externally, with the instructor. Whether psychologists and physical educators are using analogies or explicit instructions, information should be conveyed using terminology that is objective, meaningful, understood by all parties, and culturally appropriate. For instance, if describing the positioning of the arm, a reference to a 90° angle would constitute an objective and appropriate reference for individuals who have studied geometry, but the description of an object that includes a right

angle—without specifically referring to its geometry—might prove more effective for those that have not.

Unfortunately, the nature of the research investigating analogy and explicit instruction has primarily centred on the instructions themselves with limited consideration of those learning the skill. Even if analogy or explicit instructions unequivocally facilitated high levels of learning and performance in the laboratory, coaches, physical educators, and sport psychologists should be wary of directly implementing fixed sets of analogies or explicit rules such as these for several reasons. First, according to self-determination theory, opportunities for autonomy and intrinsic regulation during learning help in the development of highly motivated and self-determined experts (Ryan & Deci, 2000). The prescriptive methods utilised in analogy and explicit learning research, however, afford few opportunities in this regard to the learners, especially for those using traditional explicit instructions, which permit even less freedom for exploring the learning environment due to the large volume of information. Motivation, particularly amongst male athletes of high school age, can also be adversely affected by the speed of learning (Horn, Glenn, & Wentzell, 1993), which typically is slower for analogy and implicit learners compared to explicit methods, as discussed in the literature review. The differential effects of the instruction on levels of motivation should represent an important consideration for researchers, coaches, educators, and applied sport psychologists that, to date, has received limited attention.

Worryingly, many aspects of the research designs also correspond with models for performance-oriented motivational climates, which are associated with maladaptive motivational responses and decreased motivation (Ames & Archer,

1988), rather than mastery-oriented climates (e.g., Ames, 1992; Ntoumains & Biddle, 1999). In this regard, the research methods typically lack variety, offer learners limited control or autonomy, emphasise outcomes rather than mastery, and are designed to minimise mistakes. Even the aim of most researchers in analogy and explicit learning—to investigate the between-groups effects of instructional type—is characteristic of performance-oriented motivational climates as it is rooted in comparisons. According to Roberts and Kristiansen (2010), the criteria set by applied practitioners and educators as measures of success and failure influence achievement behaviours, cognitions, and ultimately motivational climate. In classroom settings, climates that are diverse, challenging, encourage autonomy, promote personal development, and are tailored to the learner are associated with more adaptive motivational behaviours, such as greater task positivity and increased effort (Ames, 1992). In applied settings, athletes and students often have diverse goals and unique motivations for participation (Roberts & Kristiansen, 2010), consequently, the concept of applying a verbal instructional strategy that is driven primarily by performance outcome concerns (i.e., choking) with limited consideration for motivation, development, and individual needs appears problematic and restrictive. Even if verbal instructions—whether analogical or explicit—are successful in preempting the negative effects associated with conscious processing in skilled performance later on, these advantages may offer limited utility if those methods also promote performance-oriented motivational climates, discourage participation, and, by extension, prevent ascension to higher levels of skill in the first place. Indeed, it would appear counterproductive to stringently apply analogy or explicit-based interventions based on the current evidence without consideration for other aspects

of learning, performance and well being, which will themselves also have evidence-based frameworks. For researchers, educators, and practitioners alike, greater emphasis must be placed on first assessing the needs of the students or performers and then consulting the appropriate research to determine appropriate practice, rather than applying—or even imposing—research on them.

As such, for coaches, physical educators, and applied practitioners, analogy and explicit instructions may not constitute complete working philosophies in themselves, but instead two possible tools within an eclectic approach that takes account of the interaction between the learner, their environment, and the activity. Indeed, such integrative approaches that draw upon a range of theoretical models and concepts ‘best fit the mission of applied sport psychology’ (Poczwardowski, Sherman, & Henschen, 1998, p. 199) and are particularly helpful when assessing athletes’ needs (Strean & Strean, 1998). Potentially the most significant advantage of eclectic approaches, however, is that the needs of the learner dictate the adoption of the relevant theoretical models.

One such model that might guide the application of verbal instructions that emphasises the importance of the performer is the constraints-led approach to motor skill acquisition. For proponents of this framework, environmental and task constraints interact with a range of individual characteristics—including motivation, cognition, language capabilities, physique, and emotion—to self-organise movement (Davids et al., 2008). From this perspective, the application of either analogy or explicit instructions without considering the relationships between these various constraints could hinder the search for viable motor solutions. According to Davids et al. (2008), however, the aim for learners is not to simply reproduce idealised

movement patterns, which is often the intention of coaches using prescriptive information, but to independently discover relevant, functional motor solutions. As novices will ordinarily lack the expertise to identify and attend to the most salient information (Hodges & Franks, 2002), the role for coaches and sport psychologists then is to facilitate the search for these solutions, sometimes by using instructions to clarify task goals to help narrow that search. Because perception and action are thought to be coupled (Davids et al., 2008; Gibson, 1979), however, coaches should be careful not to engender dependence on their verbal instruction, which will not always be available to the learner (Hodges & Franks, 2002). It is also thought that instructors should avoid excessively restricting the learner's search for effective movement patterns by inundating them with too much verbal information (Davids et al., 2008).

The complex interplay between the individual, the task, and the environment could explain, for instance, how there have been statistically significant benefits for analogy learners in table tennis tasks, but not in seated basketball shooting and high jump tasks. For example, the stationary nature of the seated basketball shooting likely afforded fewer opportunities for exploration—constraining movement to only the arm—compared to the table tennis designs, which involved more dynamic, whole-body movements due to the changing placement of the ball from the delivery machines. Given these variable task and environmental characteristics, the instructions could have varying effects between tasks, even if comprehension across learners could be controlled within an experimental design. Although these interactions might be difficult to examine in the laboratory, especially as it can be difficult to distinguish between these classes of constraints (Davids et al., 2008),

coaches, physical educators, and sport psychologists should consider how these factors might interact in applied settings when working with performers.

6.5. Future research

The results of this thesis have raised questions regarding the differential effects of analogy and explicit instruction and the methods used to examine these potential differences. From these questions, several potential lines of investigation have emerged. First, the study in chapter 3 suggested that verbal information disrupts performance in short-term motor control situations, but it is unclear if these effects are task or instruction specific and how long these negative effects might persist. Future research should aim to extend this research to additional tasks and separate each instruction into discrete blocks to gain further insight regarding the duration of any performance or kinematic deficits. It is possible that the harmful effects of verbal instruction could diminish with further trials, which could make verbal instruction useful in certain circumstances such as prior to competition (e.g., warm up), even if it might prove disruptive in the midst of or immediately prior to performance. The last study, detailed in chapter 5, has also raised the prospect that the effects of analogy and explicit instruction might differ with respect to age. Given the body of research that indicates that cognitive processing and verbal language capabilities also vary as a function of age, this avenue of research has important implications for not only future investigations involving analogy and explicit instructions, but our understanding and assessment of previous research as well. Although wholly novel tasks would address the issue identified in chapter 4 regarding the potential

interference of personal knowledge or vicarious experiences, it would not control for any differences arising from age.

This thesis has also presented a case that analogy and explicit conditions should be compared using instructional sets with corresponding attentional demands. To compare simple analogy instructions to the verbose explicit instructional conditions of the past lacks scientific rigour and misrepresents practice in the field. As it stands, previous results should be carefully considered until additional research addresses this issue. While addressing this concern, researchers in sport psychology and pedagogy should also consider incorporating newer technologies, as discussed in chapter 4, to enhance understanding regarding the effects of interventions on movement mechanics and other aspects of performance. As discussed in this thesis, performers have many different aims and motivations and it would be imprudent for researchers and practitioners to remain narrow-minded in their measures and evaluations of interventions and working practices. As technology progresses, an exciting prospect is that athletes, students, physical educators, researchers, and applied practitioners will have myriad opportunities for finding new ways to measure, assess, and appraise how they work and perform.

Even before considering newer, more sophisticated methods for instructing and refining movement, however, it is important that researchers, physical educators, and applied practitioners remember that there are many evidence-based tools available for deployment to suit many situations. The findings from this thesis do not suggest that analogy instruction, for instance, should not be used, but that analogy instruction should not be applied uncritically to any learner or performer without consideration of other, possibly more appropriate methods. Numerous strategies, such as cue

words, modelling, and implicit learning paradigms, may represent a few of the many tools available in the psycho-motor and psycho-behavioural curriculum, which are utilised as necessary to suit the learner and their circumstances. For researchers, this suggests a shift from investigating which tools work best compared to other tools, to investigating which tools work best *for the learner*. As it stands, research is often instructor or intervention focused with limited consideration of performers, their circumstances, and their environment.

6.5.1. Time for a fresh approach to research and practice?

As precise, consistent movements typically underlie success in sport (MacPherson, Collins, & Obhi, 2009), understanding the cues and information that facilitate both effective learning and the robust execution of motor skills should represent an important consideration for athletes, coaches, physical educators, sport psychologists, and movement practitioners alike. Although recent studies (e.g., Baudry, Leroy, Thouwarecq, & Chollet, 2006) have begun exploring the efficacy of SOI that promote optimal or functional execution, such as holistic rhythmic cues (e.g., MacPherson et al., 2008), much of the sport psychology literature and applied work to date has predominantly centred on the effects of debilitating cognitions with little regard for the underlying aspects of movement generation (MacPherson et al., 2009). In essence, current methods are oriented toward preventing disruption, rather than facilitating performance, which is a subtle, but important distinction. As discussed in this thesis, analogy and implicit instructional methods have fixated on limiting conscious processing to prevent skill breakdown, primarily through the restriction of explicit, rule-based knowledge during learning, rather than identifying

cues or information sources that promote or restore relevant coordination solutions in the face of performance pressure.

As one of the foremost concerns of any applied sport psychologist is to identify the psychological variables that allow athletes to perform at their best (Furley & Memmert, 2010), it is striking that the majority of the current perspectives are actually intended and, indeed, designed to limit, pre-empt, or correct factors associated with performance at its worst; a trend possibly strengthened by the incorporation of many practices from clinical and counselling psychology contexts. In this regard, approaches in therapy and counselling have overwhelmingly focused on the problems of the ‘sub-normal’ rather than aiming to assist well-functioning people to reach their full potential (Nelson-Jones, 2002). Nelson-Jones (2002) noted that ‘there has yet to be a major therapeutic approach developed by professionals, such as counselling psychologists or counsellors, who predominantly deal with normal client populations, let alone superior ones’ (p. 6). A corresponding tendency by researchers and practitioners in sport to focus on ‘fixing’ problems that negatively impact performance, rather than identifying the variables that optimise the configuration of the many degrees of freedom that constitute performance, suggests that an evolution or, at least, revision of the philosophy of practice may be prudent for addressing many of the needs of high-functioning (i.e., ‘normal’) novice and elite athlete populations.

The fulfilment of potential and optimisation of movement, however, represent a critical concern for athletes and coaches in sport—as well as students and physical educators—that should distinguish the philosophies that guide sport psychologists from those practices that pervade cognate divisions. Regrettably, despite such

differences in objectives, researchers and practitioners in sport have preferred to focus on ‘fixing’ problems that negatively impact performance, demonstrating minimal interest in exploring the methods and processes that help athletes maximise their performance and optimise movement. With the facilitation of technical change and development representing a vital aspect of the sport psychologist’s contribution (Carson & Collins, 2011), an approach that does focus on the identification of the cues and processes that promote optimal motor sequencing and execution may offer an attractive alternative or complement to the traditional cognitive or anxiety-based interventions and better suit the needs of performers aiming to maximise development and master their crafts.

To these ends, an emerging body of evidence has uncovered SOI (Reed, 1996), first discussed in chapter 3, as potential ‘aide-mémoires’ for promoting smooth, reliable execution of to-be-performed skills (MacPherson et al., 2008). Recent case studies in sport have provided specific evidence in this regard, demonstrating the benefits of such sources as sonic feedback (e.g., Baudry et al., 2006) and rhythmic information (e.g., MacPherson, Collins, Graham-Smith, & Turner, 2013; MacPherson et al., 2008). Sources of information such as these are thought to neatly convey the most pertinent information to the performer regarding the optimal properties (e.g., force, speed, rhythm), sequencing, or coordination of movements. Despite the concept’s roots in ecological psychology, particularly the work of Gibson (1979), SOI could be exploited in sport and exercise contexts to foster technical change, stabilise performance, rehabilitate injuries, and enrich skill instruction. However, for most potential SOI, there exists uncertainty regarding the consequences of specific cues and limited empirical research to help in understanding what cues

the information should provide or avoid (Hodges & Franks, 2004). Moreover, specific types of information could also be differentially effective with regard to the task and the individual characteristics of the learner (Newell, Liu, & Mayer-Kress, 2005), as this thesis has demonstrated with analogy and explicit instruction. As such, these alternative SOI could represent additional tools that could be used alongside verbal instruction as part of an eclectic approach to motor learning, as discussed in section 6.3, that emphasises the performer and not the rigid theoretical orientation of the coach or psychologist.

The problem for any athlete, student, coach, physical educator, or sport psychologist in such instances, however, is identifying the most appropriate SOI (MacPherson et al., 2008). For expert performers, MacPherson and colleagues (MacPherson et al., 2008; MacPherson et al., 2009) have advocated the use of holistic SOI (Reed, 1996) that neatly convey information regarding the whole movement and the relationships between its associated subcomponents, rather than single-focus, cognitive cues, such as verbal information, which may emphasise specific aspects of execution. Such a holistic cue was identified by an elite javelin thrower as an important priming tool for performance with quantitative and qualitative evidence suggesting that his rhythmically-oriented cue (i.e., attending to the rhythm or ‘music’ of his throw from the start of the approach to the release of the implement) helped to stabilise movement and reduce variability in both training and competitive environments (MacPherson et al., 2008). The benefits for the elite thrower notwithstanding, this very same holistic SOI may prove ineffective, however, if its properties or cues are unintelligible to the athlete or student. In this regard, novice javelin throwers may not possess the expertise to interpret or harness

the rhythmic information, in much the same way that inexperienced musicians may be unable to decipher the musical notation that skilled musicians can effortlessly exploit to produce consistent, functional playing performances. Moreover, the utility of this rhythmic SOI would likely be negligible—without significant modification—for unrelated skills, such as basketball free throw shooting, as it does not convey any meaningful information regarding the coordination or objectives of the movement.

In sport and physical education, therefore, it is paramount that SOI selection not only appropriately reflects the properties and sequencing of the movement, but also reconciles the interactions between the task, characteristics of the individual (e.g., skill level, physique, cognitive capabilities, etc.), and their environments. Assisted by the emergence and development of new technologies, an increasing number of studies have begun to explore methods for using alternative SOI in sport to enhance learning, stabilise performance, and refine skill. One such recent study (Godbout & Boyd, 2010) investigated the utility of auditory SOI for correcting the crossover technique of a Canadian speed skater for whom traditional verbal methods of instruction had proven unsuccessful. In order to help the skater recognise the deviations in his technique—especially with regard to the orientation of his skate—and achieve the appropriate positioning, the researchers placed small wireless sensors on his ankle and foot that compared his stride cycles to those of a model skater. Whenever the subject transitioned from one phase of the stride cycle to another (out of a possible four), the system would play a unique note that was matched only to that particular segment. When the phases were successfully executed in order, the corresponding sonic information produced an arpeggio—the notes of a chord played in succession— helping to facilitate synchronisation of the

subject's stride with the model by making 'music', not unlike the rhythmic cue described by the elite thrower in the javelin study. The continuous information enabled the subject to develop awareness regarding both deviations and correspondence in his technique from the model and to make the necessary adjustments in real-time, a feat that would not have been possible using traditional methods, such as verbal, rule-based information and feedback. In essence, additional perceptual information was added to the environment, helping the learner find the most effective movement solution.

In this case, the researchers argued that the selection of sonic information was the ideal SOI as speed skaters are already overloaded with visual, proprioceptive, and tactile information during performance; however, these aforementioned SOI may be adaptable for use in other sports. Haptic or tactile information, for instance, has been used successfully in clinical rehabilitation studies alongside visual feedback (e.g., Koritnik, Koenig, Bajd, Riener, & Munih, 2010) and it is often used in video games to indicate to the user when their virtual vehicle has ventured off road (e.g., Forza Motorsport 3, Microsoft; Mario Kart Wii, Nintendo), thereby serving to constrain user steering to the simulated track. It is this use in video games which may, in fact, hint at the most advantageous application of haptic information for sport: constraining and directing performers to those movements most necessary to perform the task. As technology continues to advance, researchers, applied psychologists, physical educators, coaches, and learners themselves may have greater opportunities to look beyond verbal communication and harness information that was previously inaccessible, but may prove ultimately more useful. In the meantime, physical educators, coaches, and sport psychologists must remember that access to these

various SOI is not necessarily limited only to advanced technology. Renowned high jump coach, Dr. Wolfgang Ritzdorf (2011), director of the International Association of Athletics Federation (IAAF) High Jump Centre in Cologne, recently called on coaches and athletes in athletics to move beyond reliance on verbal instruction to explore alternative techniques grounded in sensations or feelings—such as visual, haptic, or rhythmic information—and it may be time for sport psychologists and those in similar fields to follow this path as well. A transition toward incorporating myriad alternative SOI to promote movement development, rather than prevent movement failure, could present researchers, practitioners, and performers with exciting new opportunities.

6.6. Limitations and challenges

Although the designs and methodologies of the studies in this thesis were carefully considered and built upon precedent from existing literature, it would be unrealistic to assume that these designs did not have their own limitations or present significant challenges. In the study reported in chapter 3, one such potential limitation is that the order of the conditions was not fully counterbalanced. In this regard, all participants first performed the baseline conditions—with and without KR—before moving on to complete the remaining conditions, which were then counterbalanced using Latin squares. Although this design was deliberate and based on precedent in the literature (e.g., Lohse et al., 2010; Schorer et al., 2012; Winter & Collins, 2013), there still exists the possibility that the order or a factor associated with order could have influenced the results. A fully counterbalanced design would have mitigated any such possibility and also revealed whether the deleterious effects

associated with analogy and explicit instruction continue to persist after the delivery of the instruction. Another way to have gained additional insight into the persistence of the acute effects of verbal instruction would have been to separate each of the instructions from the experimental conditions into their own blocks with more throws. With the accuracy and kinematic measures, this would have afforded more information regarding the duration of these effects, although it could also have introduced issues relating to fatigue due to the increased number of trials.

In the studies detailed in chapters 4 and 5, the number of trials were specifically chosen to limit such concerns regarding fatigue, which was identified in chapter 2 as an issue in the existing literature, as well as to better reflect real-world training and competitive environments. By limiting the number of trials, however, it is possible that insufficient learning occurred for the explicit rules to engender reinvestment, as observed in earlier investigations in the literature, although the non-significant results do correspond to those of Lam et al. (2009b).

Another limitation in chapter 4 pertains to the number of trials that were digitised for the kinematic analyses, which was constrained by several factors pertaining to the biomechanical equipment and associated software. It was intended that the three studies would employ similar biomechanical measures using the same equipment and software in order to facilitate comparison across all of the research in this thesis. Because the study reported in chapter 5 was conducted in situ, real-time three-dimensional laboratory-based biomechanical technologies and software packages were unsuitable for use, as such equipment could not be utilised on location. Structural elements in the laboratory (e.g., pillars) and the high jump mats also obstructed the views of the cameras required for three-dimensional motion-

tracking capture systems, such as Qualisys (Gothenburg, Sweden). The chosen biomechanical equipment and APAS software allowed for similar, reliable, and accurate biomechanical measures across all studies, although the manual digitising required with this system limited the number of trials because of the time-intensive digitisation process. Although decisions regarding measurement trials, as shown in table 4.2 (p. 85), were supported by precedent in the literature (e.g., Hodges et al., 2005; Vereijken et al., 1992; Wormgoor et al., 2010), it is possible that subtle patterns or trends could have been missed, as not all trials were digitised for kinematic analysis.

The number of measurement trials in chapter 5 was even further reduced by the constraints imposed by working in an authentic school setting. Although other studies involving biomechanical measures have evaluated performance using only participants' best trials (e.g., Wormgoor et al., 2010), increasing the number of measurement trials would have further strengthened the research and offered greater insight into the differential effects of analogy and explicit instruction on adolescents. These logistical constraints in chapter 5 also restricted comparison in several respects to chapter 4, such as joint variability over learning, the accumulation of verbal knowledge, and average heart rate. Between time constraints pertaining to facility and student availability, as well as ethical concerns relating to the placement of the biomechanical markers and heart rate equipment directly onto the adolescent participants, there were a number of complications arising from the inclusion of school students into a multi-day, motor learning-based study. Although the findings from chapter 5 are still meaningful, particularly because they offer insight into the effects of verbal instructions on adolescents for the first time, these limitations

nevertheless altered the collection of data and the implications of these changes should be carefully considered when applying these findings in the field.

Despite these difficulties in data collection, the results in chapter 5, along with the differences observed in the literature, suggest that it is worth enduring the logistical complications to include adolescents in motor learning, motor control, pedagogical, and sport psychology-related research. Between availability, temporal, and ethical constraints, there are certainly numerous obstacles to overcome, but if adolescent motor learning and cognitive functioning, as noted in chapter 2, do differ from adults, it is necessary to persist with this line of research. In this regard, no study, no matter how well designed, will offer much relevance if it does not pertain and offer meaning to the population for which it is intended. The omission of kinematic data during the learning phase is perhaps the biggest disappointment arising from the constraints of working in the applied school setting, but its inclusion would have prevented data collection in such a setting, which would strip the research of arguably its most important element. As noted in chapter 6, while heavily controlled designs may be necessary to establish a foundation for research, the studies that follow must at some point yield to the real-world issues encountered by athletes, students, and performers. Research should not be designed for the sake of conducting good research, but should aim to best connect with real-world applications and situations.

One final matter to note in chapter 5 pertains to the height of the elastic band during the learning phase and the starting height for the high jump bar in the task-relevant pressure test. Although a similar method to chapter 4 was used to determine starting height based on Laffaye (2011), because there were multiple participants, the

height had to be set to accommodate the lowest predicted performance of the attending participants, which means that the heights throughout the study were less individualised than in the preceding chapter. With this change, however, the nature of this task was now more reflective of real-world high jump competitions, as the starting heights in these instances must also accommodate the full range of skills of the athletes present.

6.7. Concluding remarks

This thesis addressed questions arising from previous research regarding analogy and explicit instruction with the aim of appraising the effectiveness of analogy and explicit instructions on movement and performance. In producing this thesis, the research designs of earlier work were refined to incorporate instructional sets of corresponding volume, kinematic measures, task-relevant pressure, and, in the last study, adolescent learners. The rationale for these choices lay in their relevance to and reflection of applied work, which should form an important consideration in the design and administration of sport psychology-related research. The findings suggest that the advantages ascribed to analogy in the literature have been overstated and that the differences between these two instructional types are not as pronounced as previously believed. For applied work, these instructional types might best represent two tools within an eclectic approach that are used as necessary to suit the learner, the task, and the environment. For research, future investigations should consider further exploring the moderators of these two instructional types, as well as examining alternative SOI to use alongside verbal information as part of a

comprehensive instructive toolbox focused on the needs and circumstances of the performers.

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Appendix A. Information sheet (Chapter 3)

Primary Researcher:

Ray Bobrownicki

e: ray.bobrownicki@ed.ac.uk

t: 07599 717 350

Research Supervisors:

Dr. John Sproule

e: john.sproule@ed.ac.uk

t: 0131 651 6135

Dr. Alan MacPherson

e: alan.macpherson@ed.ac.uk

t: 0131 651 6647

current research



information about the current study and participation

The acute effects of verbal instruction on movement

What are the aims of this project? What are you hoping to do?

- ▶ We are looking to determine the short term effects of different types of verbal instruction on motor control

What sort of participants are you looking for?

- ▶ Healthy and active adults over the age of 18.

What will happen in the study?

- ▶ Participants will attempt to throw darts at a dartboard as close to the bullseye as possible using only the provided instructions.
- ▶ The participants with the top three performances will receive cash prizes (£30, £20, and £10 respectively)

Is anything else involved with participation? Are there any risks?

- ▶ Video footage will be collected to permit biomechanical analysis of dart throwing movement and to record throwing accuracy scores.
- ▶ To facilitate biomechanical analysis, participants are asked to wear either a short-sleeved t-shirt or sleeveless t-shirt, so that the camera can see the throwing arm.
- ▶ The physical and mental risks in this study are low, as the study does not use any invasive or stress-inducing measures. Every care will be taken to ensure safety and to minimise any possible risks.

When and where will the study take place?

- ▶ Participating students will attend one 45-minute session in the biomechanics laboratory located at St Leonards Land at the University of Edinburgh.

What sort of protection or safeguards are in place?

- ▶ This study complies with the ethical standards set forth for research by the British Psychological Society (BPS; [code of ethics and conduct](#)) and has been approved by the University of Edinburgh Moray House School of Education Ethics Sub-Committee.
- ▶ Any personal data or video footage collected during the study will only be used for its stated purpose and in accordance with the Data Collection Act. Access to data will be restricted to myself and my research supervisors, Dr. John Sproule and Dr. Alan MacPherson.

How can students get involved?

- ▶ First, to determine eligibility to participate in this research, students should complete the [study questionnaire](#) (also available online at <http://sportscienc.es/research/survey>)
- ▶ Please note that there is *never* any obligation to participate or to continue participating in this study once started; participants may withdrawal at any time *without penalty*.



[click here to complete the questionnaire](#)

Appendix B. Participant questionnaire (Chapter 3)

*** Participant details:**

Name:

Email Address:

Phone Number:

*** Date of birth:**

DD MM YYYY

- / /

*** Gender**

Male

Female

*** Do you have normal or corrected-to-normal vision?**

Yes

No

*** Do you have a preferred arm for throwing?**

Yes

No

Unsure

If yes, which one?

*** Do you have any previous dart throwing experience?**

Yes

No

If yes, please provide details (e.g., context, time, etc):

Appendix C. Participant consent form (Chapter 3)

Participant Consent Form

If you would like to participate in this study, please read through the consent statement and then sign and date at the bottom.

Researcher information

Ray Bobrownicki — PhD student at the University of Edinburgh

Participation details

This research involves using the provided instructions to throw darts as accurately at the bull's eye as possible.

Consent statement

1. I confirm that I have read the information sheet and have been provided with complete details regarding the aims of the research
2. I understand what my participation will involve
3. I understand that my participation is voluntary and that I am free to leave at any time
4. I have had the opportunity to ask questions about the study
5. I have disclosed all information regarding previous injuries or other concerns that might affect my health or participation in this study
6. I realise that all personal information will remain confidential and that any personally identifiable information will not be made publicly available
7. I agree to participate in this research

Participant's signature: _____

Participant's Name (print): _____

Date: _____

Appendix D. Pre-participation measures (Chapter 3)

Activity

Please rate your current level of anxiety before starting the dart throwing task by placing an '×' on the scale below. The scale ranges from 0 (not anxious at all on the left end) to 10 (extremely anxious on the right end).



Using the horizontal scale below, please rate your current level of motivation before starting today's throwing task by placing an '×' on the scale below. The scale ranges from 0 (not motivated at all on the left end) to 10 (extremely motivated on the right end).



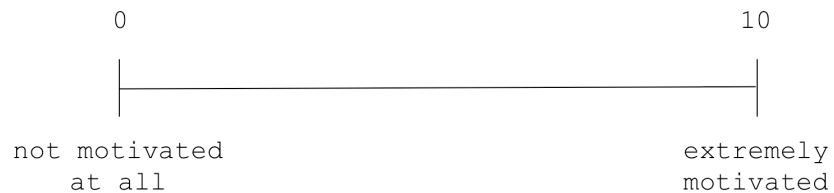
Appendix E. Post-participation measures (Chapter 3)

Activity

Please rate your level of anxiety during today's throws by placing an '×' on the scale below. The scale ranges from 0 (not anxious at all on the left end) to 10 (extremely anxious on the right end).



Using the horizontal scale below, please rate your level of motivation during today's throwing session by placing an '×' on the scale below. The scale ranges from 0 (not motivated at all on the left end) to 10 (extremely motivated on the right end).



Appendix F. Participant debrief (Chapter 3)

PARTICIPANT DEBRIEF

Thank you for your participation in this research; your time and effort is greatly appreciated. This sheet provides further information regarding the aims, implications, and expectations of this study.

What is the purpose of the research?

The main objective of this study is to investigate the short-term effects of different types of verbal instruction on motor control.

What do we expect to find?

We think that the short-term effects of verbal instruction conditions will negatively impact throwing accuracy compared to the control condition (i.e., no instruction).

What are the implications of this research?

Findings from this study could help to inform coaches and physical educators regarding how to best use or not use verbal instruction, especially in competitive or time-restricted situations.

What if I have additional questions or comments?

If you should have any additional questions, comments, or concerns regarding this study, please feel free to get in touch.

Ray Bobrownicki

ray.bobrownicki@ed.ac.uk

Room 2.18

Institute of Sport, Physical Education, & Health Sciences

University of Edinburgh

St Leonards Land

Holyrood Road

EH8 8AQ

Appendix G. Ethical approval letter (Chapter 4)



Research & Knowledge Exchange
MORAY HOUSE SCHOOL of EDUCATION

The University of Edinburgh
Old Moray House
Holyrood Road
Edinburgh EH8 8AQ

Direct Dial 0131 651 6388

Switchboard 0131 650 1000

Email rke-education@ed.ac.uk

<http://www.ed.ac.uk>

Ray Bobrownicki
c/o Alan MacPherson
St Leonards Land

11th August 2011

Dear Ray

Coaching through analogy

The School of Education Ethics Sub-Committee has now considered your request for ethical approval for the studies detailed in the your application.

This is to confirm that the Sub-Committee is happy to approve the application and that the research meets the School Ethics Level 2 criterion. This is defined as "covering novel procedures or the use of atypical participant groups – usually projects in which ethical issues might require more detailed consideration but were unlikely to prove problematic".

Ethical approval is granted subject to amendment of the participants' information to clarify that not taking part in, or withdrawing from, the research will not affect the student's status on the High Performance Programme.

A standard condition of this ethical approval is that you are required to notify the Committee, of any significant proposed deviation from the original protocol. The Committee also needs to be notified if there are any unexpected results or events once the research is underway that raise questions about the safety of the research.

Yours sincerely

pp

Dr P McLaughlin
Convener, School Ethics Sub-Committee

Appendix H. Information sheet (Chapter 4)

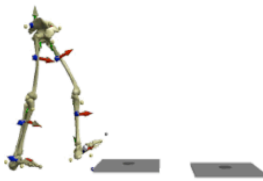


Figure 1: This animation demonstrates gait analysis using the Ariel Performance Analysis System (APAS; www.arielnet.com). Each participant will have similar, full-body models built from their jump performance data in order to investigate skill acquisition in sport.

current research



information about the current study and participation

I am currently recruiting participants for a study on skill learning in sport. Details about this research, participation, and how to get involved are provided below.

What are the aims of this project?

- The aim of this study is to investigate the types of instruction that best promote skill learning for sport.

What sort of participants are you looking for?

- Healthy and active adult males over the age of 18.

What will happen in the study?

- Participants will be asked to learn and perform a simple jumping task over the course of three sessions (1–1.5hrs each) with 20-25 total jumps per session.
- Video will be recorded of each jump for analysis with APAS biomechanics software (click [here](#) to see a video example of how APAS has been used to analyse tennis performance).
- To facilitate the biomechanical analysis, stickers and reflective tape will be used to mark joint centres on each participant's body (e.g., knees, hips, shoulders, neck, etc.) so that they are visible to the cameras.
- The analysis will yield a 3-dimensional model (see figure 1 on left) and kinematic data regarding jumping performance (e.g., horizontal velocity, vertical velocity, vertical leap height) that will provide details regarding learning and performance throughout the study.

Are there any risks or concerns involved in participation?

- The physical and mental risks in this study are low, as the study does not use any invasive or stress-inducing measures. Every care will be taken to ensure safety and to minimise any possible risks.
- To maximise the visibility of the stickers marking the joint centres for the cameras, we ask that participants wear cycling/lycra shorts and no top/shirt.

What sort of protection or safeguards are in place?

- This study complies with the ethical standards set forth for research by the British Psychological Society (BPS; [code of ethics and conduct](#)) and has been approved by the University of Edinburgh Moray House School of Education Ethics Sub-Committee.
- Any personal data or video footage collected during the study will only be used for its stated purpose and in accordance with the Data Collection Act. Access to these data will be restricted to myself and my research supervisors and collaborators, Dr. John Sproule, Dr. Alan MacPherson, and Dr. Simon Coleman.

How can I get involved?

- If you are keen to participate in this research, please complete the [participant questionnaire](#) using the links provided.
- Once you have submitted the survey, you will be contacted in due course using the telephone or email information provided therein.
- Please note that you are under no obligation to participate in this study and that you may withdraw *at any time without penalty*.

Appendix I. Participant questionnaire (Chapter 4)

The sole purpose of this confidential questionnaire is to determine if there is anything that might negatively affect your participation in this research (e.g., health, previous injury, etc.). Information collected from this survey will not be shared with anyone.

The survey is administered and stored by surveymonkey.com (for their security policy, see this [link](#)) until it is transferred onto secure, password-protected local computers and drives—no data are stored on the SPORTSCIENC.ES website itself.

After you have submitted the questionnaire, you will be contacted in due course regarding participation using either the email address or phone number you provided therein.

Please note that survey submission does **not** commit you to participation—you may withdraw from this research at any time without consequence.

Site Navigation

- current research
- participant survey
- about
- contact

participant survey

Exit this survey

* Participant details:

Name:
Email Address:
Phone Number:

* Date of birth:

DD MM YYYY
- / /

* Gender

- ☐ Male
☐ Female

* Do you have normal or corrected-to-normal vision?

- ☐ Yes
☐ No

* Do you have a preferred foot for jumping?

- ☐ Yes
☐ No
☐ Unsure

If yes, which one?

* Do you have any previous high jumping experience (e.g., physical education, athletics club, etc.)?

- ☐ Yes
☐ No

If yes, please provide details (e.g., context, time, etc):

* Do you have any injuries that might affect your performance in a jumping task?

- ☐ Yes
☐ No

If yes, please provide details:

*** Have you been prevented from participating in any sport or activity due to pain or injury in the past year?**

- ☐ Yes
☐ No

If yes, please provide details:

*** How many days per week are you active (e.g., running, exercising, sport, etc.)?**

- ☐ none
☐ 1 day
☐ 2 days
☐ 3 days
☐ 4 days
☐ 5 days
☐ 6 days
☐ 7 days

On these days, for how long are you active on average (in hours/minutes)?

*** Is there anything that might affect your participation in this research?**

- ☐ Yes
☐ No

If yes, please provide details:

Done

Appendix J. Participant consent form (Chapter 4)

PARTICIPANT CONSENT FORM

If you would like to participate in this study, please read through the consent statement and then sign and date at the bottom.

Researcher information

Ray Bobrownicki – PhD student at the University of Edinburgh

Participation details

This research involves learning and performing a jumping task over three sessions.

Consent statement

1. I confirm that I have read the information sheet and have been provided with complete details regarding the aims of the research
2. I understand what my participation will involve
3. I understand that my participation is voluntary and that I am free to leave at any time
4. I have had the opportunity to ask questions about the study
5. I have disclosed all information regarding previous injuries or other concerns that might affect my health or participation in this study
6. I realise that all personal information will remain confidential and that any personally identifiable information will not be made publicly available
7. I agree to participate in this research

Participant's signature: _____

Participant's Name (print): _____

Date: _____

Appendix K. Rating scale for mental effort (Chapter 4)

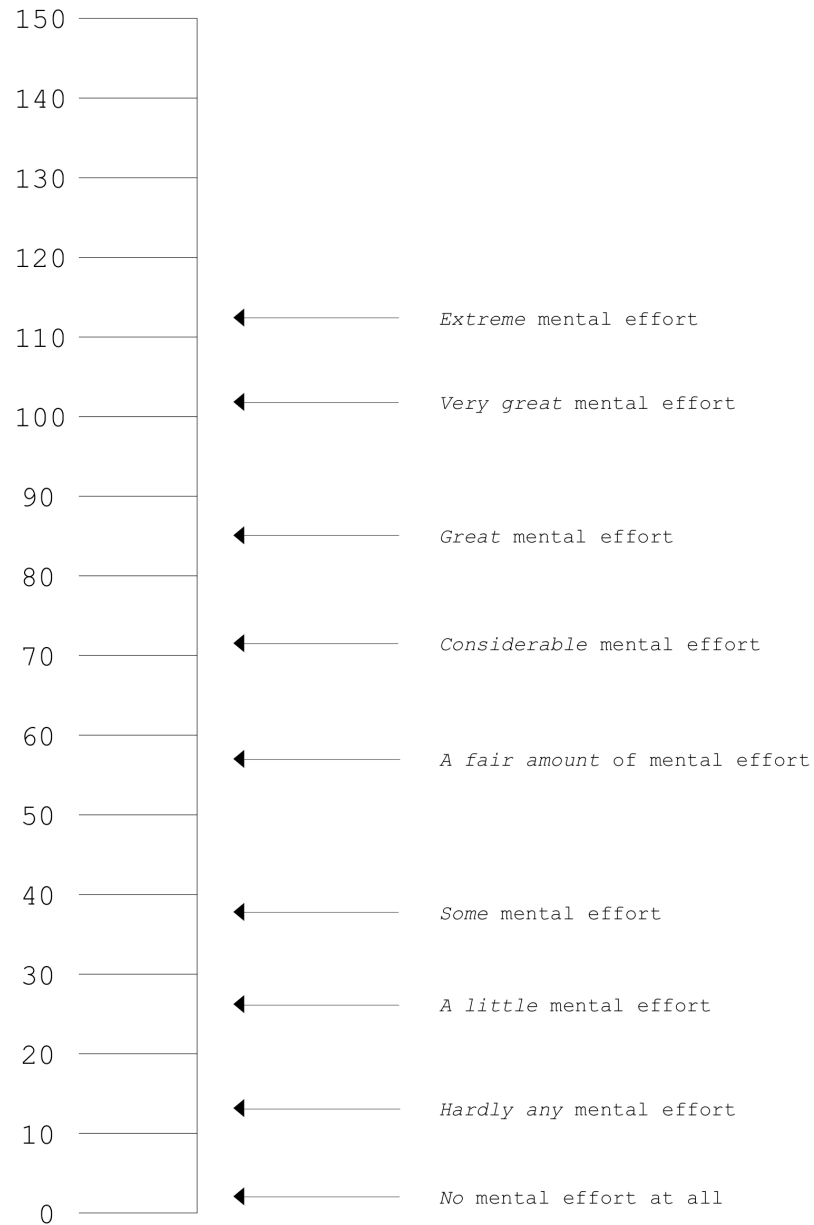
Activity 1

Mental effort is described by Zijlstra (1993) as the amount of mental resources or mental focus that one applies to a task.

Please mark an 'X' on the scale to indicate your level of mental effort during **today's** 20 jumps. You may mark anywhere on the scale from 0 to 150.

You will not be judged on the information that you provide here.

Please respond honestly.



Appendix L. Anxiety thermometer (Chapter 4)

Activity 2

Please rate your level of anxiety during **today's** jumping session by placing an 'X' on the scale below. The scale ranges from 0 (not anxious at all on the left end) to 10 (extremely anxious on the right end).



Appendix M. Verbal protocol questionnaire (Chapter 4)

Activity 3

In the space below, please describe how you performed your jumps **today** in as much detail as possible. Focus on all aspects of your jumping from start to finish and try to write down everything you remember about doing it, step by step. Please report every detail about any skills, methods, or techniques used—whether mental, technical, or physical—no matter how unimportant it may seem.

Appendix N. Participant debrief (Chapter 4)

PARTICIPANT DEBRIEF

Thank you for your participation in this research; your time and effort is greatly appreciated. This sheet provides further information regarding the aims, implications, and expectations of this study.

What is the purpose of the research?

The main objective of this study is to determine the type of instruction that best promotes motor skill learning for sport. Previous research suggests that analogy-based instruction (e.g., move your legs like scissors) produces performance that is more robust under performance pressure, physiological fatigue, and concurrent cognitive demands than skill learned using explicit, rule-based instruction; however, such studies have not compared proportionate analogy and explicit instruction conditions. By comparing analogy and explicit instruction conditions of equivalent length, this should indicate whether previous findings resulted from the type of instructions or the number of instructions.

What do we expect to find?

Unlike previous research, we do not expect to find any differences between the analogy and explicit learning groups, because the number of instructions for each condition has been controlled.

What are the implications of this research?

Depending on the results of this research, this study could impact current coaching and instructional paradigms in sport and physical education or have implications for the direction of sport science research.

If skills acquired through analogical instruction are, in fact, less susceptible to performance breakdown or "choking" under pressure as previous research suggests, then this would have ramifications for how motor skill is taught and coached across sport and education. However, if the results suggest that there is no differences in skill learning and performance with respect to instructional type, then a reconsideration or revision of current theories and research directions could be in order.

What if I have additional questions or comments?

If you should have any additional questions, comments, or concerns regarding this study, please feel free to get in touch.

Ray Bobrownicki

ray.bobrownicki@ed.ac.uk

Room 2.18

Institute of Sport, Physical Education, & Health Sciences

University of Edinburgh

St Leonards Land

Holyrood Road

EH8 8AQ

Appendix O. Ethical approval letter (Chapter 5)



Research & Knowledge Exchange
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Holyrood Road
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Direct Dial 0131 651 6388
Switchboard 0131 650 1000
Email rke-education@ed.ac.uk
<http://www.ed.ac.uk>

Ray Bobrownicki
3/2, 55 Avenuepark Street
Glasgow
G20 8LN

12 March 2013

Dear Ray

Analogy vs Explicit Instruction: Effects on gross motor skill learning in adolescents

The School of Education Ethics Sub-Committee has now considered your request for ethical approval for the studies detailed in the your application.

This is to confirm that the Sub-Committee is happy to approve the application and that the research meets the School Ethics Level 2 criterion. This is defined as "covering novel procedures or the use of atypical participant groups – usually projects in which ethical issues might require more detailed consideration but were unlikely to prove problematic".

A standard condition of this ethical approval is that you are required to notify the Committee, of any significant proposed deviation from the original protocol. The Committee also needs to be notified if there are any unexpected results or events once the research is underway that raise questions about the safety of the research.

Yours sincerely

pp Dr S Bayne
Convener, School Ethics Sub-Committee

Appendix P. Protecting Vulnerable Groups clearance (Chapter 5)



PVG SCHEME RECORD

Scheme record disclosure issued under section 52 of the Protection of Vulnerable Groups (Scotland) Act 2007

APPLICANT COPY

Disclosure Number: 200000001197167
Date of Issue: 09/02/2013
Page 1 of 1

MR RAYMOND KENNETH BOBROWNICKI
3/2, 55 AVENUEPARK STREET
GLASGOW
G20 8LN
UK



A copy of this disclosure record has also been sent to the registered body which countersigned the application and any authorised regulatory body.

Applicant Personal Details

Surname: BOBROWNICKI
Forename(s): RAYMOND KENNETH

Date of Birth: 03/03/1984

PVG Membership No. 1302 0908 0461 0357

Statement of Scheme Membership

Membership Status

The applicant is a PVG Scheme Member in respect of regulated work with children and, therefore, not barred from that type of regulated work.

Consideration Status

The applicant is not under consideration for listing by the Scottish Ministers for the workforce(s) to which this disclosure relates.

Vetting Information

Convictions

The applicant has no convictions for disclosure.

Cautions

The applicant has no cautions for disclosure.

Prescribed Court Orders & Sex Offenders Notification Requirements

The applicant has no prescribed court orders or sex offender notification requirements for disclosure.

Other Relevant Information

The applicant has no Other Relevant Information for disclosure.

END OF DISCLOSURE



006587302811

50920825

Appendix Q. Information sheet (Chapter 5)

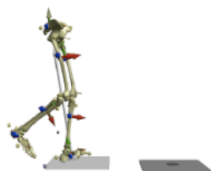


Figure 1: This animation demonstrates gait analysis using the Ariel Performance Analysis System (APAS; www.arielnet.com). Each student will have similar, full-body models built from their jump performance data in order to investigate skill acquisition in sport.

Primary Researcher:

Ray Bobrownicki

e: ray.bobrownicki@ed.ac.uk

t: 07599 717 350

Research Supervisors:

Dr. John Sproule

e: john.sproule@ed.ac.uk

t: 0131 651 6135

Dr. Alan MacPherson

e: alan.macpherson@ed.ac.uk

t: 0131 651 6647

This information is also available online at www.sportscienc.es/research



information about the current study and participation

Analogy versus explicit instruction revisited: Effects on motor skill learning in adolescents

What are the aims of this project? What are you hoping to do?

- › We are looking to determine how different types of instruction impact learning and movement in sport.
- › By doing this, we hope to develop more effective instructional programmes that maximise the time and effort of coaches, physical educators, and athletes.

What sort of participants are you looking for?

- › Healthy and active adolescent males between 12–14 years of age.

What will happen in the study?

- › Each student will each be given a set of instructions (out of a possible two) describing how to perform a jumping technique based on the high jump
- › Using only these provided instructions, students will be asked to learn this technique by jumping over a low barrier onto crash mats over the course of three sessions (Monday, Wednesday, and Friday).
- › For the third and final session, video will be recorded of each jump to permit analysis with APAS biomechanics software to determine the height, velocity, and position of each student's centre of mass (click [here](#) to see an example of how APAS has been used to analyse tennis performance).
- › These data will then be compared to determine whether there are any differences in learning, performance, and efficiency between the students arising from the type of instruction.

Is anything else involved with participation? Are there any risks?

- › Following the second and third sessions, students will complete two very brief, confidential questionnaires to determine their perceived effort and anxiety during the sessions. The purpose of these is to monitor other variables that could affect learning, outside of the provided instructions, and to allow comparison with previous research in this area.
- › The physical and mental risks in this study are low, as the study does not use any invasive or stress-inducing measures. Every care will be taken to ensure safety and to minimise any possible risks.

Is any specific equipment or clothing required?

- › Comfortable athletic attire (e.g., athletics vest and lycra shorts) and trainers are ideal for all days.
- › To enhance visibility for the video cameras for the biomechanical analysis, stickers and reflective tape will be used on the third day to mark the necessary joint centres on each participant's body (e.g., knees, hips, shoulders, ankles, and neck). To maximise the visibility of the stickers that mark these joint centres for the cameras, we ask that students wear an athletics vest with cycling/lycra shorts for the third session if possible.

When and where will the study take place? Can food be brought?

- › Participating students will attend three 45-minute sessions over the course of a single week. This time includes instruction/admin for the day; a warm-up to reduce risk of injury; rest periods; and the jumping task itself, which lasts approximately 20 minutes.
- › The overall study itself will run on Mondays, Wednesdays, and Fridays from January 2013 at the Centre for Sport during the student lunch hour. Students are welcome to bring food to the study to eat in between jumps and during rest periods.

What sort of protection or safeguards are in place?

- › This study complies with the ethical standards set forth for research by the British Psychological Society (BPS; [code of ethics and conduct](#)) and has been approved by the University of Edinburgh Moray House School of Education Ethics Sub-Committee.
- › Any personal data or video footage collected during the study will only be used for its stated purpose and in accordance with the Data Collection Act. Access to data will be restricted to myself and my research supervisors, Dr. John Sproule and Dr. Alan MacPherson.

How can students get involved?

- › First, to determine eligibility to participate in this research, students should complete the [study questionnaire](#) (also available online at <http://sportscienc.es/research/survey>)
- › Second, consent forms should be read and signed by students and parents (there are separate forms for each, both of which are available in hard copy from the College's PE Department or the University researcher, Ray Bobrownicki)
- › Please note that there is *never* any obligation to participate or to continue participating in this study once started; students may withdrawal at any time *without penalty*.

Appendix R. Participant questionnaire (Chapter 5)

This survey is also available online at www.sportscienc.es/research/survey

The sole purpose of this confidential questionnaire is to determine if there is anything that might negatively affect your participation in this research (e.g., health, previous injury, etc.). Information collected from this survey will not be shared with anyone.

The online version of this survey is administered and stored by surveymonkey.com (for their security policy, see [this link](#)) until it is transferred onto secure, password-protected local computers and drives—no data are stored on the SPORTSCIENC.ES website itself.

You may also choose to complete a hard copy version of this survey, which is stored securely in accordance with the data protection act.

After you have submitted the questionnaire, you will be contacted in due course regarding participation.

Please note that survey submission does *not* commit you to participation—you are welcome to withdraw from this research at any time without consequence.

Site Navigation

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- [participant survey](#)
- [about](#)
- [contact](#)

study survey

[Exit this survey](#)

* Student details:

Name:

Email Address:

Phone Number:

* Date of birth:

DD MM YYYY
- / /

* Year and English stream (e.g., 8 and S3)

* Do you have normal or corrected-to-normal vision?

- ☐ Yes
- ☐ No

* Do you have a preferred foot for jumping?

- ☐ Yes
- ☐ No
- ☐ Unsure

If yes, which one?

* Do you have any previous high jumping experience (e.g., physical education, athletics club, etc.)?

- ☐ Yes
- ☐ No

If yes, please provide details (e.g., context, time, etc):

* Do you have any injuries that might affect your performance in a jumping task?

- ☐ Yes
- ☐ No

If yes, please provide details:

***Have you been prevented from participating in any sport or activity due to pain or injury in the past year?**

- ☐ Yes
☐ No

If yes, please provide details:

***How many days per week are you active (e.g., running, exercising, sport, etc.)?**

- ☐ none
☐ 1 day
☐ 2 days
☒ 3 days
☐ 4 days
☐ 5 days
☐ 6 days
☐ 7 days

On these days, for how long are you active on average (in hours/minutes)?

***Is there anything not previously mentioned herein that might affect your participation in this research?**

- ☐ Yes
☐ No

If yes, please provide details:

Appendix S. Participant consent form (Chapter 5)

STUDY CONSENT FORM

To participate in the study, please carefully read through the consent statement and then sign at the bottom.

Project title

Analogy versus explicit instruction revisited: Effects on motor skill learning

Participation details

Participation involves learning and performing a jumping task over three sessions in order to investigate the best teaching methods for sport.

Researcher information

Ray Bobrownicki – PhD student at the University of Edinburgh

Consent statement

1. I confirm that I have read the information sheet and have been provided with complete details regarding the purpose and aims of the research
2. I understand what participation will involve
3. I understand that participation is voluntary and that I am free to withdraw at any time
4. I understand that my performance will be filmed during the third session
5. I have had the opportunity to ask questions about the study
6. I have disclosed all information regarding previous injuries or other concerns that might affect participation or health in this study
7. I realise that all personal information will remain confidential and that any personally identifiable information will not be made publicly available
8. I agree to participate in this research

Participant's signature: _____

Participant's Name (print): _____

Date: _____

Appendix T. Parental consent form (Chapter 5)

PARENTAL CONSENT FORM

To consent to your child's participation in this research, please carefully read through and complete the consent statement.

Project title

Analogy versus explicit instruction revisited: Effects on motor skill learning

Participation details

Participation involves learning and performing a jumping task over three sessions in order to investigate the best teaching methods for sport.

Researcher information

Ray Bobrownicki – PhD student at the University of Edinburgh
Room 2.18
Institute of Sport, Physical Education, & Health Sciences
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Consent statement

1. I confirm that I have read the information sheet and understand the details involved with my child's participation in the study.
2. I understand that I may withdraw my child from the study at any time without penalty and without affecting relationships with my child's school or Edinburgh University.
3. I understand that participation is completely voluntary and that there is no obligation to consent to my child's participation.
4. I have had the opportunity to ask questions regarding the study and my child's participation and I understand that I can contact the researcher at any time in the future if additional questions or concerns should arise.
5. I realise that all personal information will remain confidential and that any personally identifiable information will not be made publicly available.
6. I consent to my child's participation in this research.

Child's Name (print): _____

Parent's signature: _____

Parent's name (print): _____

Date: _____

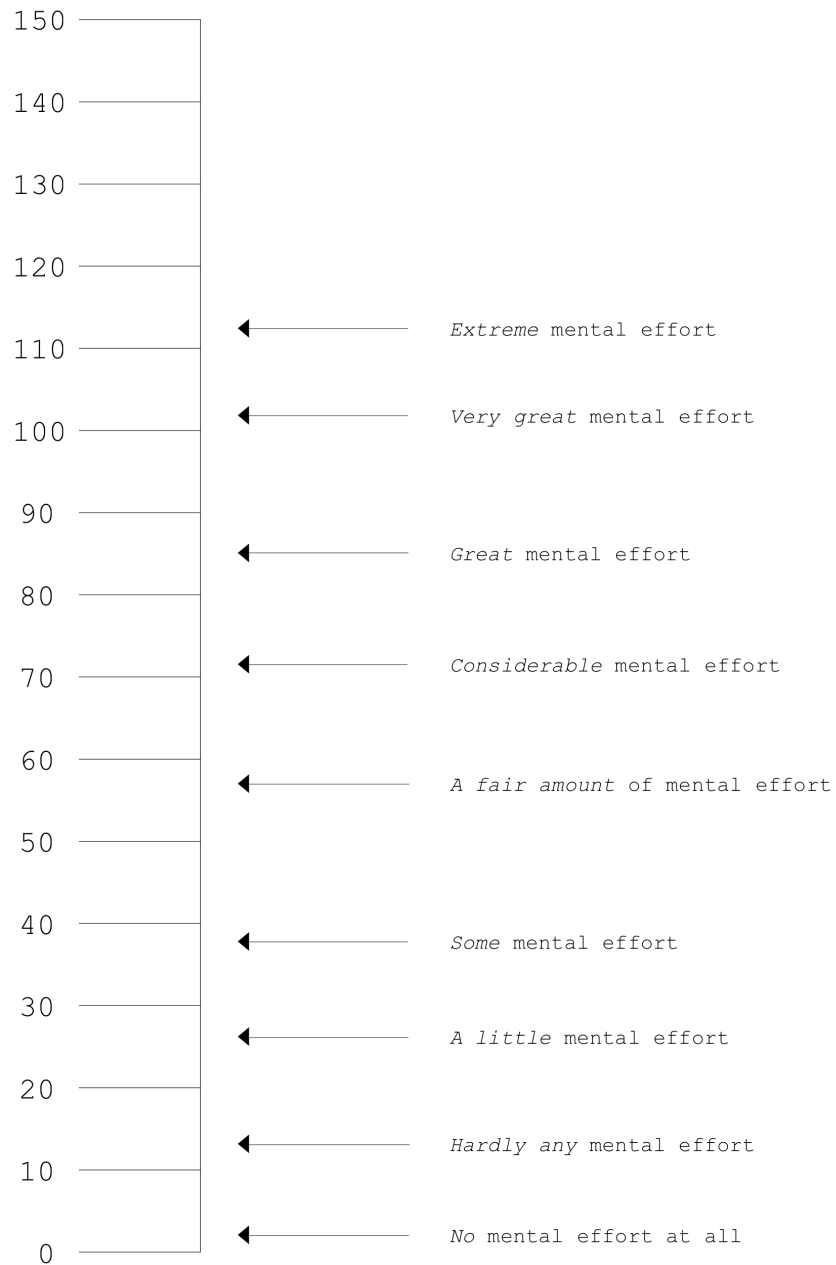
Appendix U. Rating scale for mental effort (Chapter 5)

Activity 1

Mental effort is described by Zijlstra (1993) as the amount of mental resources or mental focus that one applies to a task.

Please mark an 'X' on the scale to indicate your level of mental effort during **the second set of jumping**. You may mark anywhere on the scale from 0 to 150.

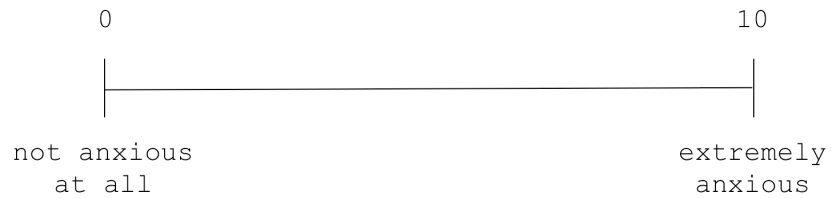
Please respond honestly; you will not be judged on the information that you provide here.



Appendix V. Anxiety thermometer (Chapter 5)

Activity 2

Please rate your level of anxiety during **the second set of jumping** by placing an 'X' on the scale below. The scale ranges from 0 (not anxious at all on the left end) to 10 (extremely anxious on the right end).



Appendix W. Participant debrief (Chapter 5)

PARTICIPANT DEBRIEF

Thank you for your participation in this research; your time and effort is greatly appreciated. This sheet provides further information regarding the aims, implications, and expectations of this study.

What is the purpose of the research?

The main objective of this study is to explore how instruction can affect learning in sport. Previous research suggests that analogies (e.g., move your legs like scissors) can promote learning that is less affected by pressure and nerves than step-by-step instruction (e.g., step 1: move leg up over bar, step 2: move leg down, etc.).

However, previous studies compared only one, single analogy to as many as 12 rules or instructions, so it was unclear whether analogies were actually more effective or simply easier to remember.

By comparing analogy and explicit, step-by-step instructions of equivalent lengths, as in this study, we should be able to determine whether previous findings resulted from the type of instruction or the number of instructions.

What do we expect to find?

Unlike previous research, we do not expect to find any differences between the analogy and explicit learning groups, because the number of instructions for each condition has been controlled.

What are the implications of this research?

Depending on the results of this research, this study could impact current instructional programmes in sport and physical education and have implications for the direction of sport science research.

If skills acquired through analogy instruction are less prone to “choking” as previous research suggests and result in enhanced learning, then this would have consequences for how sport skills are taught and coached across sport and education. However, if there are no observed differences in skill learning and performance with respect to instructional type, then a reconsideration or revision of current theories and research directions could be in order.

What if I have additional questions or comments?

If you should have any additional questions, comments, or concerns regarding this study, please feel free to get in touch.

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